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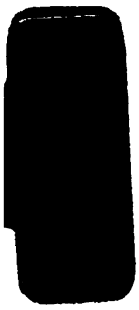

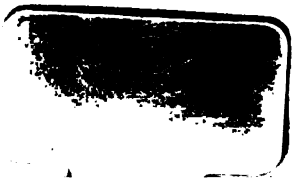

THE PRINCIPIA.

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THE

PRINCIPIA;

OR,

THE FIRST PRINCIPLES OF NATURAL THINGS,

BEING

NEW ATTEMPTS

TOWARD A

PHILOSOPHICAL EXPLANATION OF THE ELEMENTARY WORLD.

BY

EMANUEL SWEDENBORG,

LATE MEMBER OF THE HOUSE OF NOBLES IN THE ROYAL DIET OF SWEDEN,
ASSESSOR OF THE ROYAL METALLIC COLLEGE OF SWEDEN,
FELLOW OF THE ROYAL ACADEMY OF SCIENCES OF UPSALA, AND OF THE ROYAL ACADEMY OF SCIENCES OF STOCKHOLM,
CORRESPONDING MEMBER OF THE IMPERIAL ACADEMY OF SCIENCES OF ST. PETERSBURG.

TRANSLATED FROM THE LATIN

BY

THE REV. AUGUSTUS CLISSOLD, M.A.

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TO

THE SWEDENBORG ASSOCIATION,

INSTITUTED

FOR THE PURPOSE OF PROMOTING THE DIFFUSION OF ALL LITERATURE

WHICH MAY TEND TO

THE CHRISTIANIZATION OF SCIENCE,

AND HENCE FOR THE PURPOSE OF PRINTING AND PUBLISHING

THE PHILOSOPHICAL AND SCIENTIFIC WORKS OF

EMANUEL SWEDENBORG,

THIS HUMBLE ATTEMPT AT A TRANSLATION OF

THE PRINCIPIA,

IS MOST RESPECTFULLY INSCRIBED BY

THE TRANSLATOR.

ADVERTISEMENT.

The Preface by the Translator is reserved for the second volume, which is now in the press; together with the list of Errata.

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SERENISSIME PRINCEPS

LUDOVICE RUDOLPHE,

DUX BRUNSVICENSIUM ET LUNEBURGENSIUM,

ETC. ETC.

ANTIQUIS ritus fuerat, si aliquis illorum ex numero Deus votis annueret, sive thure aræ ejus injecto litaret, quod voti sui compotes facti vel solverent quod voverant, vel sertis, verbenis, et vittis aras ejus cingerent: sique opulenta fuisset domus, quod bidentes ad altaria ejus mactarent; vel annua vel menstrua vota solennesque pompas ducerent; si vero pauperes essent Lares, quod aliquibus farris aut thuris flavi micis foco altaris ejus injectis, devoto magis animo et mussitante simul ore, sacra facerent, et ei grates agerent, et pro

exiguis illis donis, ut iterum vota sua secundaret, precari ausi essent: verbo, secundum rei familiaris sortem et fortunam, templis ejus tanquam sui tutelaris, et inter numerum deorum maxime faventis, propitii et secundantis, honores instaurabant, et altaria donis struebant. Ipse, cum ante duodecim quod excurrit annos, Vestræ Serenitati aliquas micas hujus farris sive tenues pagellas rudis et incomtæ Minervæ porrigere ausus sim, læte recordor, quod illis visis, tamen annuere et favere dignatus sis; quod cum mihi voti secundi argumentum fuerat, hinc, sed ignoscas, secundum ritum antiquorum, ad aram Tuam redeo, et quamvis non divites honores templis indicere, bidentes niveos mactare, et Tibi pompas ducere queam, usque tamen acerram jam thure ejusdem generis sed pleniorem in grati animi pignus porrigere ausim; quumque litaverint olim micæ tantummodo illius farris porrectæ, spero id iterum, acerra pleniore jam muneri votivo oblata: permitte ergo, ut opusculum hoc Principiorum novorum plenum Te ut sui Tutelarem adoret, utque Philosophia hæc nova, ante Tuas aras, Tibi sacra et votiva, quum melioribus donis operari nequeo, veniat. Non orbem literatum latet, qualis Minervæ et literarum ejus Cultor et Amator

sis, qualis cultorum ejus Tutela et Favor; his fretus, propius propiusque accedere et veniam poscere ausim, et ut votis annuas, precari; si iterum annuis et faves, voti secundi faustissima auspicia erunt. Vive Serenissime Dux tot annos, quot in templis et ad aras pro annis et salute Tua vota redduntur: quod devotissime precor

SERENITATIS VESTRÆ

Perhumillimus cultor
EMANUEL SWEDENBORG.

PREFACE,

EXHIBITING A COMPENDIUM OF OUR PHILOSOPHY.

I AM apprehensive lest, at the very outset of our philosophy, particularly its First Part, my readers should be deterred from proceeding further, when they meet with views which cannot but appear strange and foreign to those which are generally received; as also with such unusual phraseology as that of a *Finite*, an *Active*, an *Elementary*, &c.; terms which are unknown in any of our philosophical treatises; that is, which are not applied to the principles of mechanism, geometry, and the elementary world. For this reason it will be requisite, by way of preface, to present a general outline of our work, and thus a key to its contents.

Every one from the light of reason may perceive, that nature, conforming to principles of geometry, is ever pursuing a most simple course; a course proper to herself, and truly mechanical. He may likewise perceive, that all things in the world originate from what is uncompounded; consequently from one single fountain-head and one primitive cause; that this primitive cause is derived into the various things which are caused (a truth which necessarily follows, if further products are to be derived from those which have already been brought into being); also that no other cause could possibly have had existence than the one which had proceeded by genealogical descent, as it were, from its first parent or simple. This cause, therefore, must be latent in the first simple; and into the first ens derived from it,

or into the first finite there must be derived a similar cause. Now since the world deduces its origin and subsequent increments, by a connected and contiguous series, from the first or single end through intermediates to another end; and since there must be present a cause, and indeed an efficient and active cause, before anything can be produced in a series; it follows that there must be a passive, an active, and as a product from both, a compound, or elementary; if therefore there be anything composite, it must consist of two principles, namely, a passive and an active; without which nature herself would be as it were in a state of celibacy or solitariness, destitute of progeny, without any new efficient, hence without effect, without series, without phenomena; in a word, without worlds. With this view of the subject then, I have endeavoured to evince that *in the Finite, which is the first in successive derivation from the Simple, is contained each principle, both passive and active,* from which, by the accession of a contingent or physical cause, arose the Composite or Elementary; and further, that in every derivative, whether a Finite, Active, or Elementary, there always coexists a similar cause, and consequently a similar faculty of producing an effect, namely, from the one into the other; thus as it were from one power into another, from one degree into another, and so on farther and farther; that in the derivatives therefore there is latent a principle similar to that which exists in the primitives; in composites a principle similar to that which exists in simples; in effects a principle similar to that which exists in causes; consequently also that nature in her various kingdoms, especially the elementary, is in the cause and in the effect simultaneously: so that from well known principles of mechanism, under the guidance of geometry and the faculty of reasoning analytically, we may, from an effect visible and posterior, safely draw our conclusions not only with regard to effects invisible and prior, but with regard to the very entities which are active and passive; nay to the very cause which is latent in all.

Let us then, in a few words, present the sum and substance of our philosophy; and in so doing begin from the first Simple. 1. We observe then, that in a Simple there is an internal state tending to a spiral motion, and consequently that there

is in it a like conatus or endeavour to produce it. 2. That in the first Finite thence resulting, there is a spiral motion of the parts. The same obtains in the other elementary Finites, in all which there is thus a like principle. 3. That from this single cause there arises in every Finite a progressive motion of the parts, an axillary motion of the whole, and, provided there be no obstacle, a local motion of the whole. 4. That if there be a local motion, there arises thence an Active, similar to the agent producing it, and differing only in degree and dimension. Hence that we admit of entities only of a threefold degree, namely, Finites, Actives, and those which are compounded of the two, namely, Composites or Elementaries. With respect to Finites we affirm, that one is generated by the other; and that all the Finites of the genus thus arising, have the greatest possible similitude one to the other; and differ only in degree and dimensions. Hence the fifth Finite is similar to the fourth; the fourth to the third; the third to the second; the second to the first; the first to its own proper Simple: so that he who knows the nature of one knows the nature of all. In the same manner we affirm, that Actives have the greatest possible similitude the one to the other; that the fifth, fourth, third, second, and first Active are all of the same nature; differing only in dimension and degree, in the same way as Finites. That Elementaries also are similar one to the other, since they are compounded of the Finite and Active; the Finites occupying the superficies, the Actives occupying the interiors; that hence the first, second, third, fourth, and fifth Element are all similar one to the other; so that he who knows the nature of one knows the nature of all. We affirm, moreover, that in every Finite there are three motions, namely, a Progressive motion of the parts, an Axillary, and a Local motion, provided there be no obstacle; nor am I aware that in these extremely simple entities any other natural motions can be assigned, or, even if they could, that there are any other than such as I have mentioned; or whether granting the motions of these entities, which no rational person would I think deny, that any other could be assigned more convenient to nature. We observe again, that all these motions proceed from one fountain-head, or from one and the same cause, namely, from a spiral motion of the

parts. This motion, inasmuch as it is the most highly mechanical, is also the most highly natural; being that in which, as is well known, the whole potency of nature and all mechanical force is inherent; and if it be granted that it is motion which is the cause of things, then no other motion can be admitted, in this case, than such as is most highly mechanical and most highly geometrical; for from its centre to its circumferences in space, a spiral is one perpetual ens, circular in all its dimensions; and as such it cannot possess in itself anything but what is most highly perfect, most highly mechanical and natural in its motion; being both as to the site of its parts and as to its motion most highly geometrical. In a Simple, however, in which there can be nothing substantial to be put in motion, nor any medium in which motion can exist, we must conceive that instead of a mechanical and geometrical motion, such as there is between parts and in a medium, there is as it were a total or pure motion, that is to say, a state and a conatus hence arising from a similar into a similar *quasi* motion; in which is latent the one only cause and primitive force that produced all the entities subsequently existing.

Inasmuch as in all its kingdoms the visible world is of so diversified an aspect, and consists and subsists in the series of parts successively and simultaneously arising, it cannot possibly have its termination in the same point in which it had its beginning; thus it cannot possibly have its termination in its own first or mediate series or line of progression, or in its first or second part; for were this the case, there would be no series in existence, neither would there be any ends; because there would be no distinctions into intermediates; consequently no element to constitute vortices; none to constitute ether or air; nothing to constitute fire; much less anything to constitute the innumerable parts of the mineral, vegetable, and animal kingdoms; in a word, there would be no world. Hence it is that, my first aim has been to demonstrate, that the first Finite derives its origin from the Simple; the second Finite from the first Finite; the third from the second; the fourth from the third; each being attended by a cause similar to that which exists in the primitive Simple, and which passes, by successive derivation, into the Finites. Hence I shew that a series of finites thus springs from

a Simple, or from the first Finite, in succession to the fifth Finite. These five Finites have a mutual relation to each other, are similar to each other, and differ only in degree and dimension, or in their ratio to each other according as they are raised to successively higher powers or degrees. Again; inasmuch as all Finites are capable of becoming Actives, or of performing gyres from a like inhering and concomitant force or cause, that is to say, from a spiral motion of the parts; and inasmuch as they can pass also into a Local motion, provided there be space and nothing in it to present any obstacle; it follows of course, that there may be a fivefold series of Actives; an Active of the first, second, third, fourth, and fifth Finite points respectively; and hence that by means of the last or fifth Active, the fire of our system may pass into our atmosphere. The same law obtains in regard to the compounds or Elementary particles; which I hold to consist of two principles, namely, Actives and Finites; the Finites occupying the surface, the Actives occupying the interiors. And inasmuch as there is thus a series of Finites and of Actives, there will also be a series of Elements such as the first or most universal Element, the second or Magnetic or vortical Element, the third or Ethereal Element, the fourth or Aërial Element; before the elementary kingdom belonging to the world has yet been fully completed. And since every single particle of each Element is elastic, encloses Actives, and possesses the faculty [*vi*] of passivity and activity; hence the first Element encloses within it the Actives of the first Finite; the second, the Actives both of the first and second; the third, the first Elementary particles; the fourth, both the first and second Elementary particles; the two latter Elements participating in each principle, although they enclose not real Actives but Elementary particles. For the Elementary particles are not only passive but active; they are consequently elastic, and are moveable in particles and volumes; the motion and mechanism of their volume depending upon the motion and mechanism of their particles; although they are not mobile and elastic in the same degree as the enclosed first and second Elementary particles from which they receive their elasticity. Thus we shew that the Elements also differ in degrees and dimension,

progressing equally with the Finites, &c., in a certain order and succession.

The series of these several subjects will be found in the work itself, as follows:—On the means of attaining to a True Philosophy. On the first simple or first natural Point. On the first Finite. On the second Finite. On the third Finite. On the fourth Finite. On the fifth Finite. On the pure material Finite, or water.

With respect to the Actives, the series is as follows:—On the Active of the Point. On the Active of the first Finite. On the Actives of the second and third Finite. On the Actives of the fourth and fifth Finite, or on fire.

With respect to the Elements, the series is as follows:—On the first or most universal Element. On the second or Magnetic Element. On the third Element, or the Ether. On the fourth Element, or the Air. On the fifth product similar to the Elements, or on Aqueous Vapour; where we finally show, that in every drop of water is contained every single thing which had hitherto existed from the first Simple, as also the whole genus of Finites, Actives, and Elementaries; consequently that in a single drop of water is latent the whole Elementary world both visible and invisible.

Now since causes and things caused are similar to each other, although they differ in degree and dimension, it follows that nature is similar to herself, and cannot be different in the larger system or elementary kingdom from what she is in the lesser; in the macrocosm from what she is in the microcosm; in a volume from what she is in a particle; hence in the elementary particle may be seen the quality of the volume, and in the volume the quality of the particle; from which we infer that the sun consists of the Actives which first originate, or those of the first and second Finite; particularly since it is the cause of all the subsequent mutations; the first motor of the things in its series; inasmuch as other things could not have successively existed except from the first Actives, or the solar space consisting of them. Consequently that the solar vortex and the vortex of the other stars consists of the first and second, hence of the most universal, Elements. That the sun itself, in the formation of its

vortex, being surrounded with a crust of Finites of the fourth genus, was thus the original chaos of the earth and the planets; and inasmuch as this crust enclosed within it the sun, or the space consisting of the Actives of the first and second order, while the fourth Finites occasioned a pressure from without, such a chaos could resemble no other than an elementary particle; in which, in like manner, the Actives exercise a pressure from within, while the Finites or Passives occupy the surface; so that it was by a process the most simple that nature produced a chaos, from which she afterwards brought forth the earths; being thus similar to herself in her greatest as well as her smallest productions. That consequently the earth, when just produced, and in proximity with the sun, consisted of the fourth Finites, and possessed in the larger system, like the Finite in the smaller, a motion of its parts, an axillary motion, and also a local motion; so that in itself it was the representation of a large Finite; and as to its local and annual motion, the representation of a large Active; that hence both in the earth and in the other planets we may see what is the quality of the Finite and what the quality of the Active in its minute boundaries; and also in the chaos what is the quality of the elementary particle. These subjects however must be referred to in the work itself, where they are treated of under the following heads:—

On the existence of the sun and the formation of the solar vortex, Part I., Chap. x.

On the comparison of the starry heaven with the magnetic sphere, Part III., Chap. i.

On the diversities of worlds, Chap. ii.

On the universal chaos of the sun and planets, and the separation of its substance into planets and satellites, Chap. iv.

On the vortex surrounding the earth, and the progression of the earth from the sun to the circle of its orbit, Chap. xi.

On the paradisiacal state of this earth, and on the first man, Chap. xii.

In the course of these chapters may be seen what are the velocities, periodical times, and centripetal forces of the planets at their respective distances from their own proper sun; also what is the cause of the eccentricity of their orbits. How the earth passed through innumerable changes before it arrived at

its ultimate orbit; how these changes were as innumerable as the circles through which it passed, or as the different distances of these circles from the sun, and its different degrees of velocity in its annual and diurnal circumvolution; in a word, how every day and hour it passed through some new change; how it was requisite for it to undergo these changes, before it could be fully perfected, or be made to consist of so many series of things arising simultaneously and successively, or be enriched with so many varieties so as to be complete in all its kingdoms, mineral, vegetable, and animal, or could cherish seeds, unfold and expand them, and thus in so delightful and varied a manner adorn its own surface. In this state of the earth, while revolving upon its axis and gyrating round the sun more rapidly than at present; or while, in consequence of being nearer to its parent sun, it meted out shorter days and years; we shew how it must have been under the influence of a perpetual spring,—a season most peculiarly adapted to the process of begetting and procreating; without which, no seeds could have grown, nor any vegetable or animal productions have originated.

With respect to the magnet and its forces, the reader is referred to the whole of the Second Part of our treatise; where I attempt to demonstrate that its force arises from the motion of the first element and of the second or magnetic, out of which are formed the solar and planetary vortices. That its magnetism consists in effluvia, which are of such a nature as to be moveable round their own axis; and that these, when set in a gyrating or spiral motion, act as the subtile element which we call magnetism; consequently that by means of these gyrations arise little vortices and ligations of these vortices from one pole of the magnet or its sphere, to another pole; and that in this manner it is that magnetism is created, as also its conjunctive force when similar effluvia pervading any other body are brought into apposition with it. That the magnet itself as such, in regard to its interior texture, consists of a rectilinear or regular situation of its parts, extending from one polar side to the other; and that hence a sphere is formed extrinsically, connected on both sides with its axis by a mechanical necessity. That the effluvia or forementioned parts are purely iron, and that iron is rendered magnetical when those parts are brought

interiorly, by friction against a magnet, either into a rectilinear or any other regular line.

We shew, moreover, that the declination of the magnet arises from the situation of these same particles of the first and second Element, or of the same element of which the vortices round the sun and the earth are formed; and that the magnet is directed into that same situation with its sphere in which are the very particles themselves of the forementioned element. That these elementary particles, inasmuch as at the same time they create a vortex round the earth must necessarily take a spiral course extending from one pole of the ecliptic to the other, and that hence arise the anomalies of magnetism.

See the Second Part of the Principia on the causes of the magnetic forces.

On the attractive forces of two or more magnets, and the ratio of the forces to the distances.

On the attractive forces of two magnets when their poles are alternated.

On the attractive forces of two magnets when their axes are parallel, or when the equinoctial of the one lies upon the equinoctial of the other.

On the disjunctive and repulsive forces of two or more magnets, when the cognominal or inimical poles are applied to each other.

On the attractive forces of the magnet and of iron.

On the influence of the magnet upon ignited iron.

On the quantity of exhalations from the magnet, and their penetration through hard bodies, &c.

On the various modes of destroying the power of the magnet; and on the chemical experiments made with it.

On the friction of the magnet against iron, and on the force communicated from the former to the latter.

On the conjunctive force of the magnet as exercised upon several pieces of iron.

On the influence of iron and the magnet upon the needle.

On the various modes of rendering iron magnetic.

On the declinations of the magnet as reduced to calculation.

Tables of observations of the declinations of the magnet in different places and at different times.

On the causes of the declination of the magnet.

Calculations of the declination of the magnet, in different years, at London and Paris.

Tables of the declinations of the magnet at Paris, from the year 1610 to 1920.

Calculations of the declinations of the magnet at Rome, at the Cape of Good Hope, and other places.

We may here add the chapter before enumerated—On the starry heaven, shewing that it is similar to the magnetic sphere: inasmuch as each is compounded of elementary particles of the same genus, most particularly adapted to vortical gyres, and being as it were born and made mechanically to the performance of this motion.

THE PRINCIPIA.

PART I.

THE PRINCIPIA.

PART I.

CHAPTER I.

ON THE MEANS WHICH CONDUCE TO TRUE PHILOSOPHY, AND ON THE TRUE PHILOSOPHER.

If the mind* [*animus*] be well connected with the organs of the senses, or in other words, if man be truly rational, he is perpetually aspiring after wisdom. The soul is in the desire of being instructed by the senses, and of continually exercising its perception from them, as from a source distinct from itself; while the senses in their turn desire to exercise their perception from the soul, to which they present their several objects for contemplation. Thus each performs and contributes to the same common operation, and tends to one ultimate object, the wisdom of the man. For this purpose there exists a continual connexion between the soul and body; for this purpose also reason is added to the senses, and hence the desire after wisdom becomes the peculiar mark and characteristic of man: unless however he desires and attains to a knowledge which lies beyond or above his senses, he is far from being truly rational, nor is there a due connexion between the senses and the soul. The senses and their various organs can receive but grossly, and in an imperfect measure, the phenomena of the world. Now there are no animals beside man who possess any knowledge beyond that of the mere senses, and of their organs disposed in

* The term *animus* is used to signify the external mind; the term *mens* to signify a more interior mind.—*Translator.*

the pia meninx of the brain. They are unable to penetrate further; and, from the want of a more subtile and active power, cannot refer the objects presented to their senses to a higher or more distinct principle. But truly the wisdom of man cannot be said to differ from theirs, if we refer the objects or operations of the world upon our senses, not to the soul and its reason, but to the same principle as they do. The sign that we are willing to be wise, is the desire to know the causes of things, and to investigate the secret and unknown operations of nature. It is for this purpose that each one consults the oracle of the rational mind, and thence awaits his answer; that is, he is eager to acquire a deeper wisdom than merely that which is proffered to him through the medium of the senses.

But he who wishes to attain the end, must wish likewise to attain the means. Now the means which more especially conduce to a knowledge truly philosophical, are three in number,—EXPERIENCE, GEOMETRY, and the FACULTY OF REASONING. First then let us ascertain whether, and in what manner, we have the power, by these three means, to arrive at knowledge *a priori*, or to reach, in natural and physical enquiries, the farthest boundaries of human wisdom.

By philosophy is here understood the knowledge of the mechanism of our world, or of whatever in the world is subject to the laws of geometry; or which it is possible to unfold to view by experience, assisted by geometry and reason. Under the jurisdiction of geometry are the *three kingdoms, the* MINERAL, *the* VEGETABLE, *and the* ANIMAL, and, if it be permitted to call it a fourth, the ELEMENTAL. *The mineral kingdom* comprehends everything in the earth of a hard, material, and terrestrial nature, whether it be metallic, stony, or sulphureous; together with every substance, either fixed or fluid, which cannot be classed as vegetable or elemental. *The vegetable kingdom* comprehends everything which owes its origin to the mineral, and which serves to adorn the surface of the earth by its growth and vegetation. *The animal kingdom* comprehends whatever increases by growth, but which lives in virtue of possessing some kind of individual soul. *The elemental kingdom* comprehends all those substances which are of themselves, and by their own nature, fluid; every particle having its own peculiar powers

of motion and elasticity. A collected volume of these constitutes an element, such as air, or ether, or others still more subtile, which we shall hereafter investigate in the course of our Principia.

Under the empire of geometry, and under the mechanical laws of motion, we may be allowed to rank the whole mineral as well as vegetable kingdoms, and indeed the animal too in respect to mechanical organs, muscles, fibres, and membranes; or in respect to its anatomical, vegetative, and organic relations. But in respect to the soul and its various faculties, I do not conceive it possible that they can be explained or comprehended by any of the known laws of motion; such indeed is our present state of ignorance, that we know not whether the motions by which the soul operates on the organs of the body be such as to be reducible to any rule or law, either similar or dissimilar to those of mechanism. *The elements* by which the earth is surrounded, and in which it floats, acknowledge mechanism and its laws to be as it were peculiarly their own; so intimately is mechanism united with the elements, as to owe its very existence to them; and indeed the method by which they are set in motion and actuated, is mechanism itself, which is thus both conceived and born of the elemental kingdom. Since then the elements called air, ether, as well as others of a still more subtle nature, are naturally and peculiarly influenced by geometry and mechanism, we have it in our power to elucidate them by the assistance of experience, the known laws of motion, and geometry united. In this first division of our Principia we treat, in part generally, and in part specifically, of the elements; of their progress from the first and most subtile, to the last which is circumfused around the earth; also of the motion of the elemental particles, of their figure, and whatever else may relate to them either as an attribute, or as essential to their nature.

It is an arduous attempt to explain philosophically the hitherto secret operations of elemental nature, far removed as they are, and almost hidden from our view. In making the attempt, however, I must endeavour to place, as it were, before the eyes, those phenomena which nature herself is careful to conceal, and of which she seems most adverse to

the investigation. In such an ocean I should not venture to spread my sail, without having experience and geometry continually present to guide my hand and watch the helm. With these to assist and direct me, I may hope for a prosperous voyage over the trackless deep. Let these be therefore my two stars to guide and enlighten me on my way; for of these it is that we stand most in need amid the thick darkness which involves both elemental nature and the human mind.

1. Experience may be defined to be the knowledge of everything in the world of nature, which is capable of being received through the medium of the senses. This definition is calculated to embrace everything, whether in the elementary kingdom, or in metallurgy, chemistry, botany, anatomy, &c., in so far as we can ascertain the manner in which it affects the senses or acts *a posteriori*. These various things may indeed be termed objects of the senses, and phenomena drawn from the great storehouse of natural things.

Let it not however be imagined that any experience, or knowledge derived *a priori*, and confined only to one man, or even to one age, is sufficient for exploring the hidden paths of nature. To crown the investigation with success, we require the experience of many ages; experience which will go on progressively increasing, till such a store of information is amassed as will supply us with phenomena calculated to elucidate any part or any series of the operations of nature.

The sciences which have now for some thousand years been adding to our experience, may at this day be said to have so far advanced, that the enquiry into the secret and invisible operations of nature need no longer be deferred. For an infinity of phenomena are already known which are capable of leading us up to this point; and besides, there are extant so many writings of so many ages, that they will sufficiently aid us in an *a priori* investigation and deduction from the first principles of things. We possess a considerable body of experiments, illustrative of the elements of ether, air, fire, and water, and also of the magnet; and if we reckon those also which have been made in metallurgy and chemistry, where nearly all the elements are called forth, and employed for the solution and condensation of bodies, we cannot for a moment doubt that the world is at

this day supplied with sufficient means to enable us to pursue our purpose.

Indeed, it does not appear that there is any occasion for that infinite variety of phenomena which some deem necessary, in order to acquire a knowledge of natural things: we have need only of the more important; of such as bear directly and proximately upon the point, and not diverge too obliquely and remotely from the series of our mechanical world and its powers. For it is to them we must owe our guidance to the first-compounded, and to us, general principles; thence by means of geometry, and aided by the leading phenomena which lie intermediately between the two, we proceed to particulars; then by a chain of connexion, to the more simple; and thus at last to the most simple, to the fountain-head, in proceeding from which they have gradually become more and more modified. The remaining mass of experiments, which are either farther removed from the first source, hence from the first and simple mechanism of the world, or which are merely collateral, and not in the same direct line of descent, may be safely laid aside as not essential; indeed, they would tend rather to divert the mind into a different course, than lead us onward in the great high road of our investigation. For a countless variety of phenomena might be mentioned, which are very remote from their first origin, and which discover no path leading to it but through multiplied and intricate mazes. Nature, branching out into such varieties of modifications, may be compared with the arterics and veins of the animal body; these, when nearest to their common fountain,—the heart, possess considerable breadth and magnitude; but become divided in their course into smaller and smaller ramifications, and at last into the finer capillary tubes, whose filaments can scarcely be discerned by the minutest observation. Let us then suppose a person ignorant of the fountain-head and origin of the blood which flows through these arteries and veins, and yet desirous to explore it by means of experiments. Surely in such a case he would scarcely commence with the smaller capillary vessels, and there institute a tedious course of dissections, with a view to trace them upwards in their devious progress: in so laborious a pursuit he would most probably be diverted from his track into other arteries and

veins, and thus remain long perplexed and misled by their numberless intricacies, before the great and regal aorta would terminate the search. Nay, by such a plan, a still further source of error, and consequent removal from the heart, might arise in the section through arteries into veins, while aiming at the contrary direction. Nature may be also likened to a labyrinth, whose intricacies you are anxious to explore. Fruitless would be the attempt to wander through all its windings, and take note of all their directions; for in this case the difficulty would only grow the more inextricable, you would only pursue your footsteps in a circle, and recognize the self-same spot when most elated by the prospect of emerging; so that if you would gain with ease, and possibly by the shortest road, the exit of the labyrinth, you must reject the senseless wish of exploring all its intricacies; rather planting yourself at some intersection of its paths, strive to ascertain somewhat of its general figure from the circuitous route you have already trodden, and retrace if advisable some of your steps. Thus may you easily ascertain the course leading to its outlet, and obtain the clue to direct you through all its mazes; and when you have familiarized yourself with their plan, you may throw aside even the clue itself, and wander about in the labyrinth fearlessly without it. Then, as if seated on an eminence, and at a glance surveying the scene which lies before you, how will you smile in tracing the various sinuosities which had baffled your judgment by multiplied and illusive intersections! But let us return to actual phenomena, and leaving similitudes pass on to the subject itself. By too great an accumulation of phenomena, and especially of those which are very remote from their cause, you not only defeat the desire of scrutinizing the occult operations of nature, but plunge yourself more and more into a maze, where you are perpetually drawn aside from the end in view, and misled into a distant and contrary region. For it is possible that many things of seemingly opposite natures may exist from one and the same first cause; such as fire, and water, and likewise air which absorbs them both. Thus a confusion arises as well from their contrary and heterogeneous natures, as from their endless variety, and a very diffused and indistinct notion becomes presented to the mind. After the experience of so many

ages, if a person should be importunate, and desirous for still further knowledge, confessing that in these respects he is still needy and ignorant, it is no wonder that he should be unable to arrive at the knowledge of mundane things so as to reason from principles and causes; for were he possessed of the greatest possible accumulation of facts, they would only serve to increase the difficulty of attaining his end.

In the state of ignorance in which we are at the present day, we can derive knowledge only through experience; not merely our own individual experience and that of our own age, but the experience of the whole literary world and of numerous ages: for after we have obtained an acquaintance with what the learned world has discovered, we are individually enabled to superadd experience of our own, and thus continually to become more enlightened. I affirm, therefore, that at this day we are made wise only by means of experience; nor can we arrive at wisdom by any other path. It is impossible to receive knowledge immediately from the soul; man attains it only through the medium of organs and senses. The first fountain of science springs from these sources, and it is by means of the connexion existing between these, and the faculties of reason and judgment, that we acquire a perception of objects: that is to say, it is only by means of experience received through the medium of organs, and thence transmitted to the mind, that we are capable of becoming wise. The means therefore of all our wisdom are to be found in experience; without which the human race would be barbarous, merely animal, and irrational. Suppose a person, destitute of education, left wholly to himself with wild beasts and apes, or advancing to manhood without the society of any animal,—What kind of brute would he be? What intelligence would he enjoy from nature? What would be the operation of his higher aura, or [*animi*] mind, on the organs of his body; or, at a riper age, what would be the operation of the organs of his body on his mind? Man is made and formed, and distinguished from the brutes, by education alone; in the process of which, the organs that mediate between the mind [*animi*] and the body, being brought into exercise, are as it were cultivated and fashioned; and exercise so arranges the elements enclosed

in the small membranes and organs, as to enable the most subtile tremors and motions to pass and repass throughout them, and opens as it were those secret and intricate avenues which lead to the most subtile and active substance of our nature. It is by means of this that the oracles of the rational mind are issued and disclosed. All the sciences we possess, we have received from experience. By experience we know how to discharge the duties of a citizen, and to live with others in moral society; we learn to be prudent, we learn to be philosophers. By experience we acquire the arts of war and fortification; we learn to train soldiers in such a method, that each individual of himself conjointly with the battalion, and the battalion with each individual, is enabled to stand securely against the attack of the enemy. We learn by experience to construct ships, to build houses, to cultivate fields and gardens; arts which first originated from a sense of their necessity, and being thence practised, attained perfection through the experience of ages. Let us instance the sciences of metallurgy and chemistry. Metallurgy, which commenced in an experimental knowledge many ages before the flood, continued its progress until it attained the improvement it at present possesses; an improvement which is such, that we now fully understand how the hardest rocks can be penetrated; how shafts of different kinds can be worked though mountains themselves, passages bored to the bowels of the earth, and its metallic veins opened and explored; how laboratories and furnaces should be constructed for the purpose of extracting and smelting the better part of the ore, and how the metal is afterwards to be made into bars and shaped with the file; with many other particulars which relate to the hidden course of the vein, and the formation of the metal itself. These discoveries are all owing to that great instructress experience, who seems to have been the more ingenious in regard to this art, and the more desirous of learning it, because it produces silver and gold; means to which all things are obedient, which procure subsistence and honors for their possessors, and which, upon that account, so greatly interest mankind. From experience we learn the extensive science of chemistry, or the art of separating metals, and all the constituents of vegetable nature, both by the dry and

the humid method, as it is called. How sulphur, spirits, oils, and liquids of various kinds, may be elicited by means of fire or a menstruum; how the lighter parts, and likewise the heavier, and metallic substances, may be dissolved by the menstruum, and made to sink to the bottom, or ascend to the surface; how the flame and fire are to be tempered, and to what degree of heat a body capable of being subdued by it should be subjected; or how a slow fire devours substances, or a stronger and fiercer descends deeper into their compages, penetrates into their inmost principles, and separates them into parts. But this entire science is the offspring of experiment. We are indebted to experience therefore for all our knowledge, while experience itself is indebted to the senses, by means of which objects are subjected to the ratiocination of the mind, and thus we are finally enabled to acquire wisdom. In proportion, therefore, as the supply of experience is the more abundant, and the better disposed and distributed throughout the organs; in proportion as the mediate organs are more exact in their harmony, and better adapted in their figure; and in proportion as a more elevated path is thrown open to the most subtile principles of things by series and continuity, in the same proportion may man become wise. But, after all, alas! what is our wisdom?—truly such as what is finite is to what is infinite; and in respect therefore to infinite wisdom, nothing.

The reason for which we are to acquire knowledge by means of experience, and to investigate the nature of objects and set them in a distinct point of view, by subjecting them to the operation of the reasoning faculty, is, that we have an active and most subtile principle and soul, to which the subjects of our enquiry can be submitted; whereby we are enabled, through the comparison and series of many phenomena, to form a judgment respecting them; and, by considering their equations, similitudes, analogies, and analyses, to discover their causes by a course of geometrical and rational investigation. Man is distinguished from brutes by reason alone: in other respects we are mere animals and organized forms. Our senses are similar to those of brutes, and we have an interior texture not unlike theirs: our sole distinction consists in that invisible or reasoning faculty, that more subtile active principle, to which we are

enabled more inwardly to refer objects, and consequently to perceive them with more distinctiveness. It cannot be denied but that there is a connexion between the organs of the senses and the soul, and that the affections of the organs of the senses can be in a moment transmitted to the soul by means of that connexion: it is equally certain that those affections thus pass out of a more gross medium into a more subtile one, and that these mediums are contiguous and succeed each other in order. For if the affections impressed on the organs be instantly perceived in the soul, and if the organs of the senses be of a grosser substance than the soul, it follows, that all perception passes out of a grosser into a more refined medium, by means of contiguity and of the connexion existing between them, and thus arrives at that most active principle which is the primary and ultimate constituent of man. We can form no idea how this perception is experienced in the soul, but by comparing it with the elements. For there exists a first and a most subtile element, and others that are successively more gross; thus there are air, ether, and others. If the particles of a grosser element should by any means be excited, either individually or collectively, so as to experience either an undulation, or a tremulation, or any other kind of modification, such modification would pass out of this grosser medium into a more subtile one. If these mediums were in such close contiguity and connexion as to form together one volume, then the motion arising in the grosser element or medium would be more sensibly felt in the more subtile one. The tremulation of one particle, or of its superficies, in the grosser medium, might cause an undulation among the particles, or in the volume, of the more subtile medium: and if mediums and elements of a still more subtile nature were present and intermixed, the same affection which was tremulous in the first and undulatory in the second, might cause a local motion among the particles of the third. It follows from hence, that when a motion passes from a grosser medium into one that is more subtile, it becomes successively more sensible; and if more sensible, then more distinct. We are distinguished therefore from brutes by this circumstance, that their perceptions do not penetrate to so subtile a medium as they do in man, but that they stop as it were midway, where perception is less sensible

and less distinct. Let us suppose the organs of the senses to be mechanical, and formed according to the mechanism of the motions existing in the elements; let us suppose that there are membranes which are acted upon either by the air, or the ether undulating; let us suppose also that these membranes are of different kinds, either more gross or more subtile; and that the brain has a hard meninx, a soft one, and one more subtile still; (for it is observable that all things, both in the vegetable and animal kingdom, go out into ramifications, which become more and more subtile till they arrive at the highest degree of fineness, as is the case with the muscles, with the nerves, with the veins, with the membranes;)—if, in this case, a motion arise in a grosser membrane, and pass into one that is more subtile, the effect will be exactly the same as in passing from a more gross into a more subtile medium. If the mediums or membranes be so contiguous and in such mutual connexion, that a motion impressed on that which is more gross can be instantly perceived in that which is more subtile, then the least motion in the more gross becomes greater, and of a higher kind, in the more subtile, and consequently more sensible and distinct. That the membranes perceive, is a very common form of speech among anatomists. But let us leave these subjects, from which we only mean to infer that we ought to be instructed by the senses, and that it is only by means of the experience conveyed from them to the mind *(animum)* that we are able to acquire knowledge and wisdom.

I have before observed, that man is formed by the education and exercise of his faculties, that the organs which mediate between the senses and the mind are fashioned by continual culture, and that without culture and exercise those organs would be closed, as it were, and man would be like a brute. The slowness of his progress from infancy to manhood, contributes in a most important and essential manner to the forming and opening of such organs or motions in the most subtile membranes; not to mention the construction of the brain itself. For we do not arrive at adolescence till after fifteen or twenty years, or more; whilst the larger, more robust, and muscular animals, arrive at maturity in between three and five years. In the meantime, our organs are yielding and soft, like wax, which enables them to

receive the natural and simple motion of the elementary world, and to accommodate it to themselves in a gradual and orderly manner; so that whilst they consolidate, the vestiges and elements, or figures and diversities, of the motions they are exposed to, can be fashioned within them; for the reason that, whilst the different parts are fitted to each other and increase in size, they grow hard by degrees. If, therefore, during this interval, the parts which as yet are weak, tender, and easily affected, be agitated by perpetual and long-continued motions, their tender texture being thus constantly in motion and agitation for a long time, and always acquiring form during its growth and expansion, is rendered pliant and yielding to the innumerable different motions of this description. But on the other hand, if an animal arrive sooner at maturity, and its parts receive a fixed arrangement before they are accustomed to such motions, they must be rendered more rigid, and become in a manner callous; whence the more subtile parts, and those which approximate to the most simple, afterwards yield with difficulty to the motions impressed, and afford no passage through themselves but what is gross and obscure, just as if the impressed motion had to pass through a thick coat; for the greater rigidity and thickness of the coats of the organs and membranes renders them less obedient to subtile tremors. The longer, therefore, an animal is in arriving at maturity and the full tension of its parts, the more open may the passage to its most subtile principles or organs be rendered, and the thinner will be the coats of its membranes and parts; the more obedient also to the motions impressed on them, and the more numerous the ramifications into which it will extend; consequently, the more perfect will the animal become, provided the means be employed which are capable of perfecting him; and which consist, as was before said, in perpetually calling his faculties into use, cultivation, and motion, by means of education.

Although, however, we acquire wisdom by experience alone, it does not therefore follow that they are the wisest who are the most experienced, or who retain a great deal in their memory; I affirm only, that they are capable of becoming wise, and that experience is the medium which leads to wisdom. For experience, considered merely by itself, is science, and not wisdom; it is

only the threshold and entrance by which wisdom may be approached. He who is possessed of scientific knowledge, and is merely skilled in experiment, has taken only the first step to wisdom; for such a person is only acquainted with what is posterior, and is ignorant of what is prior; thus his wisdom does not extend beyond the organs of the senses, and is unconnected with reason; when nevertheless true wisdom embraces both. In the state of ignorance in which we live, experiment is but a kind of phantom, a mere effigy which simulates the appearance of wisdom. At this day they are reputed the most wise, who are most experienced, or most versed in experiment; by making a display of which they are immediately regarded as persons of acute judgment and refined perception; and the more so, if they are possessed of eloquence and an harmonious series and connexion of language; still more so, if they know how to captivate the ears of their auditors by a sweetness and melody of voice and accent. But those alone arrive at the goal of true wisdom, who not only possess the greatest store of experience, but have also their organs so formed and disposed, from the senses even to the soul, by means of exercise, and so well and closely connected and arranged, that they can adduce from their treasures of experience, whenever required, such instances, and such only, as are adapted to the immediate occasion; by the similitude, analysis, and comparison of which, they are enabled to reason distinctly, and to arrive even at the causes of the subject of enquiry, or at the things antecedent and prior to it, by a chain of argument. But experience taken by itself, as was said before, is not wisdom. A painter who is possessed of colors and dyes, and can draw lines with them, is not therefore master of his profession; nor is a mere manufacturer of instruments capable, on that account, of skilfully touching the strings of the harp and educing harmony. He who possesses an ostentatious number of books, is not necessarily a man of learning, nor does he, for that reason, deserve the laurel, for his wit may probably be of the dullest kind. Or, to consider the matter nearer and more interiorly, the historian who has turned over a multitude of books, and has learnt from them the fates and vicissitudes of former ages, and the lives and exploits of all the heroes, is not on that account wise, and

worthy of being raised to official eminence; that is, he is not, from that circumstance alone, an able member of the commonwealth, and more deserving than others to be seated at the helm. He ought to have the events and transactions of former times so arranged, by means of his organs and the various chambers of his memory, as to be able, on every occasion, to refer to such historical circumstances as are most similar and analogous to the case in hand; and these, and no others ought, as if spontaneously, to offer themselves to his reasoning powers. Nor is he even then wise, unless he has previously penetrated, by means of a rational philosophy, into the causes and principles of things; in order that he may afterwards be able to argue upon the present emergency from causes and principles, or from reason and *a priori*, and to form more certain conclusions by means of a connected chain of inferences; and, having his counsels derived from such a source, may be able, by the timely adoption of proper measures, to provide for the welfare of the state.

Hence it follows, that he who retains all the natural experience of the world laid up in the storehouse of memory, is not on that account a philosopher, and capable of knowing the causes of things, and of reasoning *a priori*; for to do this, he must know moreover how to digest all things analytically by means of geometry and rational philosophy; and must possess the faculty of reasoning philosophically, which consists in a certain situation and figure of the organs, as connected with the rational faculty, produced by continual cultivation and use. It is thus that a man may first become a philosopher, may be enabled to penetrate into the causes of things, and may afterwards from causes speak by means of experience.

Hitherto we have treated of the first medium leading to philosophical wisdom, or the knowledge of the mechanic or organic world: we now proceed to the next.

2. The second medium leading to wisdom, by which the arcana of invisible nature may be unlocked or revealed, is geometry and rational philosophy; by means of which we are enabled to compare our experiments, to digest them analytically, to reduce them to laws, rules, and analogies, and thence to arrive at some more remote principle or fact which

before was unknown. Mere experience is incapable of unfolding anything, and of reducing it to its more simple parts; it cannot so arrange facts that bear a resemblance to each other, as to discover what was unknown by observing its similarity to things that are known; for this is the office of reason. But to retain a great abundance of observations in the memory, and afterwards to form conjectures or conclusions respecting things unknown from their similitudes and analogies to such as are known, and thus to ground our discourse upon a connected chain of experiments, is a method of attaining wisdom at once familiar and natural.

The whole world itself, as consisting of the elements and of the mineral and vegetable kingdoms, is a pure system of mechanism; and so also is the animal kingdom, as to its anatomical organization. The science of mechanics itself with all its powers, geometry with all its figures and quantities, and philosophy with its comparative and proportional reasoning, sprang solely from the elementary world; they are the offspring of the elements of which they were conceived and born. The science of mechanics is the law of nature herself as she acts and moves in the elements; and it is according to this that her parts have their motion both in the simple and compound; without the elements and their regular disposition and motion, no mechanism could exist. As therefore the science of mechanics is the law of elementary nature, it follows that the world itself is governed by suitable laws and rules, and that the whole is a grand piece of mechanism: a circumstance which becomes the more evident when we observe that nothing is in a state of motion without observing some mechanical law. If motion be supposed, both the figure of that motion must be supposed, and also its space: consequently, if there be figure and space, as well as motion, the whole is mechanical, and is capable of being reduced to the laws of geometry. The very attributes of motion, without which it cannot exist, are geometrical, being figure and space. When we form an idea of any body, however small, as soon as we consider it as limited we regard it as something geometrical, because it possesses figure and quantity according to its peculiar dimensions: it may also be considered as subject to the laws of proportion

in itself, because it possesses distance between its limits, and between one point of that distance and another there exists proportion: the case is the same in other instances. Thus not only motion, but every finite thing in a state of rest, possesses attributes which are purely geometrical. Geometry, therefore, accompanies the world from its first origin, or first boundary, to its last, and is inseparable from it: so also do the principles of mechanics, though they might be different in a world differently formed, and in elements differently formed and arranged: and thus, although there may be innumerable finite worlds, nothing can exist in any of them which does not depend upon some mechanical principle, and a like principle of geometry must be common to them all. Whoever supposes the world to be any otherwise constituted, must take refuge in occult qualities, only to conceal his ignorance, and to preserve his reputation as a philosopher in the republic of letters. Every well-formed mind must admit that the world is composed of elements; that elements are composed of particles; that particles are composed of spaces and figures; that figured particles are the result of motion, and of situation or disposition suited to such motion; and that motion and situation have their proportions.

As all things in the world are mechanical, and possess motion and limits, it also follows that the smallest natural things, as well as the largest, flow in a mechanical order, and that the smallest and largest are governed by similar mechanical principles. And though the particles of the elements are invisible, and in a great measure elude the observation of the senses, yet as they are fluent and bounded, they are geometrical, and must flow and subsist in a mechanical manner: the case must be the same both with the objects that are within, and with those that are above, the sphere of our vision. That the equilibrium and motion of the greater bodies follow the common and known laws of mechanics, is certain; we see it to be the case in the vortex of our sun, in the planets, in the earth, in the satellites that revolve within the boundaries of the greater vortex, and move elliptically through their proper orbits with perfect regularity exactly as would smaller bodies if they were made to revolve in a similar figure. These immense masses are governed

by the same law, or the same centripetal and centrifugal tendency, which is observable in small bodies that are made in like manner to revolve round their centre. A similar proof is afforded by the animal kingdom also; in which we see the motions of whales, elephants, and other animals, effected by means of tendons, nerves, muscles, and fibres, which move the various members of the body, such as the feet, arms, fingers, &c. In all animals we see the blood and fluids flow and return through the large and small arteries and veins, and through their proper ducts and vessels; and either, as in vegetables, proceed to certain fixed boundaries, or continually retrace their steps and perform the same course over again. We also see how the lungs perform their alternate motions, like a pair of bellows, according to the influx and reflux of the air. That all these motions are mechanically effected, we have ocular testimony, since the nerves, fibres and muscles, all properly configurated and adapted to the respective movements, lie open to view: whence we are enabled to investigate these primary mechanical and hydraulic machines, to handle as it were these original motive powers, and to demonstrate that they all depend upon mechanical principles. The same observation is true of the organs of the senses. For it is known that the undulating air flows into the ear, and occasions in its tympanum a motion imitative of itself, that it afterwards continues the same motion throughout its malleus, incus, cochlea, and various channels and instruments of sound, towards the interior parts; so that the undulation of the air seems to have formed a mechanism of its own, with a view to be received and transmitted farther towards membranes of the same kind lying within, for the reception of sensation. What a wonderful mechanism is apparent in the eye, where there are so many coats, so many humours and fibrils, so many nerves leading from them towards the interior parts!—by means of which whatever is received from the ether in the eye, insinuates and propagates itself from thence towards the coats of the same kind in the meninges, and thus more and more deeply: so that the ether seems to have formed in the eye a mechanism of its own, by which its undulations can be received, and be farther transferred towards the interior parts, till sensation is experienced. These contrivances and minute machines, most exactly

formed, according to the laws of mechanics, for the reception of the modifications of the air and ether, it is in our power to view, examine, and scrutinize in all their parts, and to see how their membranes and coats are prolongated, as it were, from the interior recesses of the head into the light of day, in order that the elements may be able to operate immediately upon them, and more speedily convey the impressed motions from thence towards the interiors; an operation which is effected gradually, by first affecting the coats of the same kind, and then such as are smaller and possessed of more acute sensibility. From these observations we may conclude, that the animal body is governed by mechanical principles; to which conclusion we may add, as will now be demonstrated, that the same kind of mechanism is observable in the smallest animal as in the largest. For there are animalcula so small as to evade the observation of the keenest eye, and to be discoverable only by the aid of the greatest magnifying power: yet these, diminutive as they are, have feet, legs, and other members, which are moved in the same manner as the members of great whales and elephants; they have lungs which inhale and respire the air; they have a heart which circulates some kind of blood through their little frame; they have sight, and probably hearing, consequently they have coats and meninges, which are protracted and expanded from within the head towards the eye and ear till they come in contact with the external element; they have humours, fibres, and vessels receptive of the motions of the elements, by which those motions are transferred towards the membranes and meninges that are contained within this little animated point: they have also their desires, pleasures, gratifications, loves, parturitions, and emotions of their animal spirits. Now as there is the same mechanism, and equally ingenious, in the smallest animal body as in the greatest; and as the former seems, on account of the more subtile texture of its membranes, to possess quicker and more perfect motions than those whose bodies are more gross (for the smaller animalcula are in a manner nearer to the more subtile and simple elements); what other conclusion can be drawn than that nature is the same, is like herself, and is governed by similar mechanical principles, in the smallest finite existences as in the greatest? Thus also in respect to the elements; if they

have motion it must be by particles [*particulatim*],* consequently they must have particles of which they are composed; and the particles of one element must have the particles of another element within it and without it, with which it must form equilibrium and contiguity. But this will be explained in the course of the work; I only wish to state here, that in these invisible and smallest elementary figures there is the same kind of mechanism as in the greatest; that it is the same in whales and the smallest insect, in an immense inhabited globe and a little revolving ball. If geometry be considered, it will be found to be always like itself. For if there be space, it is always accompanied by figure; if there be motion, figure too is always inseparable from it; if several spaces and figures be imagined, there will always be a ratio between those spaces and figures; there is the same ratio between the greatest numbers as between the smallest; as for example, there is the same between 100,000,000,000,000 and 500,000,000,000,000 as there is between 000,000,000,000,01 and 000,000,000,000,05. The case is the same with the differences in the infinitesimal or differential calculus; that is, there is the same ratio between (dx) and (dy) as there is between the essential integers (x) and (y), though (dx) and (dy) are differences nearly equal to nothing. Thus also in occult nature, or the smallest corpuscular existences; there cannot be any other proportion between the smallest elementary particles, than what exists between the greatest bodies of the same figure, unless there be collateral considerations that cause dissimilitude. It is only that which is not finited or bounded that is exempt from the laws of geometry; but as soon as anything is limited by boundaries or motion, or both, it is immediately connected with figure and space, and comes under the empire of geometry, which has for its subject whatever has boundary or figure. The mechanism of minute things is better, purer, and more conformable to rule, than that of things which are large and intricately compounded. For in minute things the weight, circumference, surface, and figure are less; their modification, which is the cause of change, is less; and consequently there is less dissimilitude, fewer points of contact, and less friction: thus in minute

* Particulatim posse moveri debent.

things there is nothing to prevent the whole from being geometrically put in motion: a circumstance which cannot be hoped for in great bodies, for the reasons just mentioned.

As nature* operates in the world in a mechanical manner, and the phenomena which she exhibits to our senses are subject to their proper laws and rules, it follows, that nature cannot thus operate except by means of contiguity and connexion. Thus the mechanism of the world consists in contiguity, without which, neither the world nor its mechanism could exist. Unless one particle were to operate both upon another and by means of another, or the whole mass were to operate by all its particles respectively, and at the same time at a distance, nothing elementary, capable of affecting or striking the least organ of sense, could exist. Contiguity is necessary to the production of every operation. Without a perpetual connexion between the end and the means, the existence of elementary nature, and of the vegetable and animal natures thence originating, would be impossible. The connexion between ends and means forms the very life and essence of nature. For nothing can originate from itself; it must originate from some other thing: hence there must be a certain contiguity and connexion in the existence of natural things; that is, all things, in regard to their existence, must follow each other in successive order. Thus all things in the world owe their existence to their mutual dependence on each other, there being a connexion, by mediums, from ultimate to ultimate, whence all things have respect to their first source from which they derive their existence. For if all things had not respect to their first source, but only to some intermediate link, this intermediate would be their ultimate: but an intermediate cannot exist but from something prior to itself, and whatever exists from something prior to itself cannot be the ultimate, but only an intermediate; or else if it were the ultimate, the world would stop short at this ultimate and perish, because it would have no connexion with its proper ultimate by something antecedent. These remarks have reference to the sub-

* Nature is the first beginning of the mutations which are in the world. This first beginning is a force; hence nature is a force. But since these mutations exist by motion, this force is a motive force. Hence universal nature is a universal active or motive force. (See the *Cosmologia Generalis* of Christian Wolff.)—*Translator.*

ject of existence. With respect to the subject of contingencies, or modes and modifications, which exist both from ultimate and simple, and from intermediate substances, neither can these be otherwise than continuous and mutually connected, depending successively on each other from one end to the other. Thus must all things, both such as are essential and such as are contingent, necessarily have a connexion with their first substantial principle: for they proceed solely from simple or compound substances; and as these substances depend, for their existence, mutually upon each other, it follows that the modifications related to those substances must be dependent on the same connexion. We see then that there is contiguity in all things, and that nature produces them by means of the connexion, extending from one end to the other, both of substances and causes. Whatever is first produced by such connexion must continue to subsist by the same means. We see in vegetables that there is a connexion between the root and the extremities, and every part of the extremities: that there is a connexion between the intermediate stem and the little twigs and leaves, by infinite filaments stretching from one shoot, branch, and stalk, into another, and thus affording secret passages for the continual reception of aliment. It is in such a contiguity that vegetation itself consists; and the life of the vegetable afterwards continues in the same contiguity and connexion: the part where it ceases no longer grows, but withers and dies, and drops useless from its stem. The case is the same in animals; parts cover over parts, and grow by contiguity. Both the nervous and membranous system is coherent and contiguous. There is no part in the whole animal to which the fibres, muscles, veins, and arteries do not extend; no fibre, which is not derived and ramified from some larger nerve; no nerve, which does not proceed from the medulla spinalis or oblongata and its teguments; and no vein, but what originates from that great one which flows immediately from the heart. The medulla and its teguments, with which the nerves are connected, are in contiguity with the membranes of the whole brain; its grosser coats are contiguous to its more subtile ones; the dura mater to the pia mater; the pia mater to the more subtile parts; and thus the contiguity is continued till it arrives at those simple active substances, from which all

motions or affections can afterwards reflect and expand themselves to the most subtile principles of all. Hence it is manifest that there is a continual connexion of the whole body with its minutest parts. If the connexion with any part were broken, that part would no longer partake of the life of the rest of the body, but would die, having lost its contiguity. If a connecting part, mediating between the grosser and more subtile motions or affections of the body, were to be broken, a resemblance of death would be superinduced upon the part. Hence also the poets have compared the life and fates of man to a continuous thread woven by the Parcæ, and feigned that if this thread were anywhere severed, his life would also be cut off and all the series of his destinies. But to return to our elementary world. If we admit a contiguity, we immediately have a cause for every contingent occurrence; but if there be no contiguity, no contingent circumstance can occur in the world, because there is no cause for its occurring either in one manner or in another. The cause and reason of all effects and phenomena is to be found in contiguity and connexion. If this *contiguum* of nature were to begin to be diminished and rarified, the world, as to the phenomena existing in it, and every part would pant as it were for breath, and be reduced to its last extremity. Thus all things depend on something contiguous to them; as the body depends on life, hearing on the air, sight on the ether. The equilibration of all things in the elements depends also on contiguity. The air itself could not undergo and communicate pressure, according to its altitude, nor could it force up the mercury in the barometer to indicate the approaching weather, unless its particles were contiguous to, and incumbent upon, each other, and unless the pressure and weight of its lowest particles, or those nearest the earth, were balanced with those which are above the clouds: neither could any particle of air expand itself, nor so exact a proportion exist between the degree of its expansion and the superincumbent weight, without the contiguity, continuous action, and consequently equal pressure, of the circumfluent particles. Neither without contiguity could the air undulate so distinctly and harmoniously, or actuate the drum of the ear in a manner conformable to itself, and operate as it does in every direction. Without the existence of other

more subtile elements, the particles of which are contiguous to each other, from the sun to our globe, by means of which a contiguity is effected between the sun and the eye, it would be impossible for the eye to behold the sun; there would be no light, and no sight or perception of light: but as the eye enjoys the sight and sensation of objects which are nevertheless at a distance, it is a sign that there is some kind of contiguity between itself and these objects, such as the sun, the stars, and the planets. In short, no reason can be assigned for any phenomenon, unless we admit the existence of contiguity or connexion; for no phenomenon can exist, except in something contiguous. The conclusion therefore is, that the mechanical world has its consistence in contiguity and connexion.

That there is a contiguity and connexion in the elements, appears also in men and animals, who are composed, and in a manner formed, according to that contiguity and connexion. In some, the connexion of things existing in the elements appears to be natural, for all the harmony in the elements conspires with the connexion of their organs, whence a corresponding harmony is felt in their organs without any assistance from rules: for the mechanism of the world to some men and animals is natural, or is familiar to them by nature, without any other instructor. Thus we find the hearing delighted by harmonious sounds and the concordant vibration of musical strings. Musical harmony has itself also its own rules, its own proper geometry: but this we have no need to learn in order to perceive the harmony; we have it in the ear itself and the organs of hearing, which are in harmonious coherence. By harmonious and accordant sounds we are exhilarated, affected, dissolved away; but discordant sounds give us pain. For sound, when harmonious, glides on to the soul as it were spontaneously by means of the connexion between the two, and with a smooth and even stream; but when it is discordant, the connexion is immediately disturbed and tortured, and the sound does not arrive at the soul without occasioning pain. It is from the same cause that some persons are musicians by nature, and know how to accompany their voice with an instrument, or an instrument with their voice, immediately, without any master; although music, like all other things, has its own geometrical

rules and proportions. The eye, also, is capable of feeling whether anything be harmoniously proportioned or not: and if it be, and its mechanism be well arranged, the soul is immediately delighted through the eye. Thus the eye discerns whether a tree be growing and flourishing in a manner to affect us with a sense of beauty and delight; whether the ornaments of a garden be conformable to the rules of art; whether certain mixtures of colours harmonize together; whether an edifice and its parts be constructed according to rule; whether anything be beautiful and therefore delightful; whether the face of a man or of a virgin be handsome: and all this it does without understanding the rules in conformity with which beauty consists; although nevertheless beauty has its proper rules, and consists in the analogy and harmony of parts. As, too, there is a like connexion and harmony between the eye and the mind, therefore whatever is harmonious immediately extends, with uninterrupted course, to the mind [*animus*], which it exhilarates and expands; while all things that are deformed, and not in agreement with analogy, occasion it a certain degree of violence. We have still more striking tokens of harmony in the other senses, as in the smell and the taste, so that by the senses alone we can discover whether the parts of a substance be angular or round, or what is their form and figure. The mechanism, therefore, of some things is natural to our senses. As brute animals also are formed according to the connexion subsisting throughout the world and its elements, so also the organs of their senses are in like manner endowed with a connectedness and harmony similar to that of the elementary world itself: hence we behold indications, in many of them, of a certain natural mechanism. We see the spider construct her webs in a geometrical manner, drawing radii from a centre, and connecting them together with polygons and circles; and when it is finished, she places herself in the middle, and lies in ambush for her prey. We see the beaver build himself a house, neatly fitting one beam to another; exactly as would an architect, when proceeding by geometrical principles and rules. We see how birds form their nests, in various ways, of boughs, straw, reeds, earth, and clay, so that it would be scarcely possible to frame them better by the exactest rules of art. They know

how to give a round form to their nest, to attach it to the eaves of buildings or boughs of trees, to contrive supports for it, and to unite together its parts so as to leave in the middle a cavity lined with chaff or feathers, within which in soft repose they may lay their eggs, and pass the period of incubation. To say nothing of bees who form to themselves sexangular hives of wax, and of numberless other instances. These exemplifications may suffice to point out and confirm the existence of a natural mechanism: for the senses are formed in accordance with the mechanism of the elementary world, and everything is in agreement with the senses which is in agreement with the connectedness of their structure.

But though the world is constituted in a mechanical manner, and is composed of a series of finite things which have their origin by means of the most various contingents; and though the world, being of such a nature, may, with the aid of geometry, be explored by means of experiment and the phenomena that exist in it; it does not therefore follow that all things whatsoever that are in the world are subject to the empire of geometry. For there are innumerable things which are not mechanical, nor even geometrical; such as the Infinite, and whatsoever is in the Infinite. Geometry is conversant only with things that are finite and have limits, and with the figures and spaces thence originating, together with their several dimensions; but that which is infinite is without and above the sphere of geometry, being regarded by it as its origin and first beginning. For the finite has its origin in the infinite, without which it can neither begin nor continue to exist: to this infinite it is that everything finite has reference, not excepting geometry. Geometry, therefore, is itself subservient to that most vast Infinite, from which as from their fountain-head such an infinite number of finite things emanate, and owns that there is nothing in itself either similar or analogous to it. There is then an Infinite, which can by no means be geometrically explored, because its existence is prior to geometry, as being its cause. There are also many other things, the nature of which, though they originated from the Infinite, and began to exist together with the world, has not yet been discovered by any geometry or any reasoning philosophy: for instance, that

intelligent principle which exists in animals, or the soul, which, together with the body, constitutes their life. We may perhaps learn the mechanism of the different organs, and may know how they are moved by means of the muscles, tendons, fibres, and nerves,—by the feet, arms, and other members; how the undulating air is received by the membranes and instruments of the ear, and is represented within the mazy chambers of the brain by means of sounds; we may also come to know how the ether exhibits a modification of itself in the eye, and runs through the membranes of its nerves till it arrives at the meninges of the brain; how a motion dissipates and expands itself out of a grosser into more subtile medium, and thus arrives more distinctly at the most subtile membranes; perhaps too we may know how a motion is received by some subtile active principle, and how it does not and cannot remit its elastic undulation [*elaterem suum non remittat*], till choice has determined it into act by means of the will; we also see every emotion and mode of the soul performed mechanically in the body: still, after all, what that intelligence itself is which is in the soul, which knows and is able to determine, which knows and is able to choose, and to let one thing pass out into act and not another, we are obviously ignorant. For it does not consist merely in the relation or reaction of motions proceeding from grosser mediums, through such as are more subtile, to that contexture of active principles where perception takes place; for this exists in the elements, in vegetables, in all the world, yet there is not, on this account, an intelligent principle in everything belonging to the elementary world. In the souls of brutes, too, there are the marks of a certain intelligence. Birds know how to form their nests according to harmony and mechanical rule; they know how to deposit their eggs, to sit upon them, to hatch and rear their infant brood; offices which are variously performed by various species according to the difference of nature and disposition in their tender offspring. Other animals are aware of the approach of winter, and make timely provision against it. Ants erect their hills, and diligently carry and store up in them such things as ought to be under shelter during the winter. Bees know to suck honey and wax from flowers; to construct sexangular cells, and to store them with honey: the elder

ones know how to send out their offspring with a view to form new colonies; to kill their useless companions and drones, and to cut off their wings; in a word, they know how to provide for futurity, that they may not perish with hunger in the winter when no sustenance is to be found abroad; not to mention other marks of their prudence and natural intelligence. We behold the spider construct her artful snare with diametrical lines and connecting circles, and then lying in the middle, she so places her feet, as instantly to feel into what part of her web the prisoner has fallen. What marks of prudence excite our wonder in the fox! What artful frauds and cunning tricks does he practise! What wonders of a like nature are observable in innumerable other animals; and all flowing naturally from a grosser kind of soul. But what is the nature of this intelligence, pertaining to the active ens of animals as an inherent quality, geometry has hitherto been unable to discover; and we are yet ignorant whether the laws to which it is subject are similar to those of mechanics; although it cannot be denied to have laws, because it has an orderly connectivity, and is natural. In the soul of brutes there is some idea of this intelligence: in man it is more distinct and rational: in the Infinite it is infinite, and infinitely surpasses the comprehension and sphere of the most rational intelligence. There are also many other things which occur in the world that cannot be called geometrical. Thus there is a Providence respecting all things, which is infinite in the Infinite, or in the Being who is provident in the highest degree; and there follows from hence a connexion or series of consequents, according to which all circumstances are determined and arranged, by causes and the causes of causes, toward a certain end. We see from experience, and *à posteriori*, that there is such a connexion of contingencies, from causes and their causates, in producing a given end; but to know the nature of this connexion, *à priori*, is not within the province of man or of geometry. There are also innumerable other things which we in vain endeavour to explore by geometry and *à priori*; as, perhaps, the nature of love. We see, *à posteriori*, that it has its consistence in the connexion of things; that it exists independently of the organic body; is antecedent to corporeal pleasure; and, being conjoined in the animal with intelligence, produces every-

thing which can conduce to the preservation and continuation of its kind. The ancients regarded love as being of great moment, attributing to it the production of the universe; and many will assert that traces of intelligent love are to be found in vegetable and inanimate subjects. There are probably infinite other things, of which we have no knowledge whatever, that own no obedience to the known laws of mechanics. Hence we may conclude, that there are qualities in the soul that are still very remote from mechanical apprehension: so that, did we even know all the mechanism and geometry of the visible world, of animal organization, vegetation, or any other department of nature, there still are infinite things with which we are unacquainted.

But since the intelligence in the soul is not mechanical, but only the mode in which the soul operates, we next enquire what that is in the soul which is not mechanical, and what its essential rational and intelligent principle which is not subject to known laws. The rational principle [*rationale*] in the soul does not consist in knowing many things which the world naturally exhibits and represents to the senses; for this knowledge refers itself to the world, the senses, and experience. The rational principle does not consist in knowing the figures and spaces in which motions terminate; for this is the province of geometrical science. The rational principle does not consist in knowing the proportion between figures and spaces, and the other rules and proportions of motion, by which the world acts and produces its phenomena; for this belongs to nature, mechanics, science, and philosophy. But the rational principle consists in knowing how, and at the same time being able, to arrange into such order and connexion the reasons or proportional facts known from the world, as to view their analogy: yet this presupposes an active principle, or a certain force, impelling into motion all those things which inhere as it were scientifically in its organs; that is, it presupposes a soul. The rational active principle derived from this, consists in knowing how, and in being able, actually to elicit from analogy a third or fourth truth previously unknown. A subsequent rational principle consists in being able to form a certain series and connexion of such reasons or proportional facts, consisting of things known and unknown in

succession, till it distinctly arrives at the end it has in view: to accomplish which, all the sciences must coöperate with reason; as geometry, mechanics, rational philosophy, and abundant experience. The rational principle in the soul, therefore, is the continual analysis of those things which are scientifically as it were inherent in its organs.*

These observations may suffice respecting the second means of arriving at a mechanical knowledge of the secret things of nature; we now come to treat of the third means, or of the faculty of reasoning.

3. The third means by which we may arrive at a true philosophy in cosmology, and at the knowledge of occult nature, is the faculty of reasoning. Let experience and geometry be given; that is, let a man possess the utmost store of experimental knowledge and be at the same time a complete geometer, and yet suppose him to be deficient in the faculty of just reasoning, or of comparing the several parts of his knowledge and experience, and representing them distinctly to the soul; he can never attain to the mysteries and inward recesses of philosophy. Knowledge without reason,—a heap of many things in the memory without judgment to separate and distinguish them, and without the talent of deducing the unknown object of inquiry from certain known data, by means of the rational or geometrical analysis,—in a word, the possession of the means without the faculty of arriving at the end, do not create a philosopher: nor will any laurel-wreath, plucked from the sacred hill, be entwined by the maids of Parnassus around the brow of him who is destitute of this talent. The faculty of reasoning justly, and of arriving at the end in view by the proper means, which are experience and geometry, is the characteristic of the rational man. But a like faculty of reasoning

* The term principle so frequently used in this and other parts of the translation is not always to be found in the original. The expression in the original is *ipsissimum rationale & intelligens—rationale activum*. The word principle is used by the translator from not knowing what other to adopt. As commonly employed by others, it conveys no definite idea; the reason is, that no definite idea is commonly entertained of order and series. But the moment a definite idea of order and series in nature is entertained, the term principle assumes a fixed and definite meaning: and in this case a principle in its general sense is a first beginning of an order or series.—*Translator*.

is not given, and at this day cannot be given, to all. Some there are who are unable to attain to it through some fault of nature; being deprived of it from the first moment of their birth by disease or defect derived from their parents. We see children born to the figure and likeness of their parents; with the same face; with the same disposition; with the same situation and arrangement of their organs; with much the same faculty of reasoning as was possessed by their parents; and inheriting their very diseases, which in this case are called hereditary. Some also, by defect, are born blind, or deaf, or idiots, having the brain of improper weight, dimensions, or form, who therefore are able to acquire nothing, or very little, of the faculty of reasoning, by any use or practice; for their organs cannot be so disposed as to afford a distinct communication of motions from the senses to the soul and its reason: they may, indeed, possess a passage to the more subtile interiors, but only such as is irregular, indistinct, obtuse, and obscure. There are others who labour under no natural defect; but who, having been deprived of the advantages of a proper education, and being without experience, have been unable to acquire any talent for reasoning; the way that leads from their senses to the soul may be compared to the passage of rays from the sun to the eye, when they have to make their way through a dense or cloudy medium; their animal motions do not arrive distinctly at their active principles, but stop, as it were, in the middle of their course; the images of the motions, as in mere animals, seeming scarcely able to travel any further, because the organs are not yet fashioned, as it were, by use and cultivation, that is to say, are not yet rendered contiguous to, and in conjunction with, their more subtile life,—the organs are indeed potentially there, but require exercise to form and fit them for use. But when, by experience and science, they are fitted to motions and tremors of every kind, there are then innumerable things inherent in them, which are capable of being, by some active principle or motive force, produced into act, and so arranged as to give their possessor the capacity of reasoning, or of displaying the operations of his rational faculty. Unless a motion is able to penetrate successively, by means of contiguity, from grosser principles towards such as are more subtile, it either stops in

grosser or mediate principles, or passes into a state of obscurity. In proportion, therefore, as a man's store of experience or experiments is greater, and its disposition and distribution through the organs is more perfect; in proportion, also, as the harmony of his mediate organs is more exact, and their figure better adapted to the conveyance of every kind of tremors or vibrations; and in proportion as the passage is more deeply opened, in series and continuity, to the most subtile principles of all; so much the wiser may the man become.

It was said above, that the faculty of reasoning is acquired by cultivation, or, that we are rendered rational by use and cultivation; and likewise, that we are capable of being rendered more rational in proportion to the length of time through which we advance to maturity, or in proportion to the number of years which are required to form and consolidate the organs.

But that the nature and quality of the faculty itself may be clearly understood, it must be observed, that our sciences and experimental knowledge must be so disposed and harmoniously diffused throughout the organs, that immediately on the approach of any active principle or power, all those things so disposed which are of a similar nature, should immediately vibrate and run as it were to meet it, and present themselves to the soul simultaneously; but no others, except obscurely, by virtue of their common connexion. This may be illustrated by the comparison of a hundred musical strings of equal length and tension, one of which being moved or struck, all the others vibrate without being touched, run as it were together into the same sound, and present themselves at once in concord to the ear. This being premised, it follows that our wisdom is proportioned to the acquisitions of our memory.

Suppose, then, the means to be in our possession, and that we have acquired the power and faculty of reasoning, and have brought it into actual operation, we may arrive at true philosophy, or may be able to discourse and frame dissertations on the phenomena of nature from their genuine causes, by the aid of experiment: nay, we may arrive at the very fountain-head from which all things that appear mysterious are derived. With respect to the knowledge of the elements, which is the chief subject of discussion in the present volume of our PRINCIPIA, I

confess that it appears to be of the most occult nature, being remote and imperceptible to the ken of the senses. Nevertheless, the motions of the volumes or bodies contained in the elements are perceptible to our sight and hearing. Thus elementary nature places before our eyes the most diverse phenomena, by which, as by so many tokens, she seems to reveal herself; now sporting half naked before our view, now concealing herself; yet by her various phenomena ever displaying her image, as in a mirror, to observation. For we see that all things are acted upon and put in motion according to rules; they all flow from the motion and situation of corpuscules of different figures in mutual contact. If, therefore, experiment and geometry be called to our aid, I have no doubt, under the auspices of such leaders, of the possibility of arriving at some knowledge of the things in our world that appear not to our sight; especially since elementary nature, as just observed, is perpetually sporting so beautifully before our senses, and entertaining them with her illusions, to geometers and philosophers always shewing her face half unveiled. Let us then call the proper means to our assistance, and we shall probably arrive at the true causes and knowledge of things occult. Unless, however, principles be formed to which experiment, observation, and geometry agree, they are to be regarded as the mere figments and dreams of a delirious mind. But if our principles be agreeable to experience, and are confirmed by the test of geometry, then it may be permitted us to liken them to truths, and to declare them to be a legitimate offspring. How far this may be affirmed of my PRINCIPIA, it is for the reader to decide.

4. By a true philosopher, we understand a man, who, by the means above treated of, is enabled to arrive at the real causes, and the knowledge of those things in the mechanical world which are invisible and remote from the senses; and who is afterwards capable of reasoning *à priori*, or from first principles or causes, concerning the world and its phenomena, both in physics, chemistry, metallurgy, and all other sciences or subjects which are under the empire of mechanical principles; and who can thus, as from a central point, take a survey of the whole mundane system, and of its mechanical and philosophical laws. For the mechanical world of nature is not unlike a

spider's web, and natural philosophy may be compared to the spider herself. The spider chooses a situation which will permit her to fasten her threads to the various parts of surrounding objects: the radii which she draws she then makes to meet in a certain centre, and these she ties and connects together, at various distances, by circles and polygons; her design in which is, to render all the parts of the sphere which she occupies contiguous one to another. Then betaking herself to the middle or centre, she so plants her feet on the threads or radii, as to be able to perceive the smallest particle that may alight on any of the radii at any distance; and whilst thus lying in ambush, she knows immediately whether anything has precipitated itself into her snare, and feels in what part of her web the prey has fallen; for by that very radius and no other, out she rushes instantly and seizes her entangled victim. Now Nature herself closely resembles this spider's web; for she consists, as it were, of infinite radii proceeding from a certain centre, and connected together, in like manner, by infinite circles and polygons; so that nothing can happen in one of them which does not immediately extend itself to the centre, from whence it is reflected and dispersed through a great portion of the fabric. By means of such a contiguity and connexion it is that Nature is able to perform her operations, and in this her very essence consists; for wherever this contiguity is interrupted, wherever a thread of the web is broken, so as to dissolve the connexion between the centre and its circumferences, there Nature herself ceases and terminates. Natural Philosophy is capable of taking her station, with Nature herself, near this centre to which all natural things have reference, or in which all the motions or affections of all the circumambient parts are concentrated: she is capable of instantly knowing and feeling anything that occurs in the surrounding peripheries, what it is, and whence it comes; and is able to explain the reasons, to her companion Nature, why the phenomena occur successively, and by a certain necessity, at such a certain distance, in such a certain manner, and in no other. In a word, she is able, from the centre, to take a simultaneous view of her infinite peripheries, and to survey all her mundane system at a glance: thus she does not take up her abode in the mere outward cir-

cumference, or entangle herself in the complexity of her operations.

Were it possible, by such means, first to bring to light elemental nature, afterwards the nature of the metallic kingdom, then that of the vegetable, and finally that of the animal, how great would be the advantages which the world would reap from the discovery! For if we knew *à priori* the causes of the things observable in these kingdoms, and were able to dissert upon them, commencing from the same principles and causes from which Nature herself brings forth and manifests her phenomena, every one might then know the objects which Nature has in view; every one might then give responses as from the inmost recesses and from behind the veil of Nature's temple; every philosopher would be a Themis or Apollo, that is, would be acquainted with all the phenomena that can exist, and would comprise the vastest sciences within the compass of a nut-shell. But if any one is content with devising principles, and is so indulgent to his imagination as not to look for the evidence of them in geometry, nor to concern himself about their agreement with physical facts; or if he forms to himself a distinct theory for every series of phenomena, and for every series of experiments contrives new links of connexion, and, when his fragile ties give way, endeavours to restore their coherence with clumsy knots,—can such a one be ever admitted to these oracles? Surely Nature will only smile at him either as a bungler, wasting his time in dreamy toil; or as an infant wishing to build nests in the air, to provide them with eggs and there to hatch young; or as a simpleton employed in making for himself wings of wax, vainly regarding himself, not as Icarus, but as Mercury,—ambitious of directing his flight towards the sun,—and believing, as the poet sings, "That he can unlock the mysteries of Delphos and of heaven, and unfold those great oracles of the August Mind, which have so long lain hid, undiscovered by the genius of any former enquirer."

No man seems to have been capable of arriving at true philosophy, since the age of that first of mortals who is said to have been in a state of the most perfect integrity, that is to say, who was formed and made according to all the art, image, and connexion of the world, before the existence of vice. All who are governed by a right mind, aspire after, nay, are intensely desirous of ar-

riving at the same degree of wisdom, as at a something which we have lost: but how far it is possible to succeed, none but the true philosopher can see; he who is only in part a philosopher, or who wishes to be reputed one, may suppose himself to have arrived at the goal, and even to have proceeded beyond it; while his fancied wisdom is after all mere hallucination. The reason why man in a state of integrity was made a complete philosopher, was, that he might the better know how to venerate the Deity—the Origin of all things,—that Being who is all in all. For without the utmost devotion to the Supreme Being, no one can be a complete and truly learned philosopher. True philosophy and contempt of the Deity are two opposites. Veneration for the Infinite Being can never be separated from philosophy; for he who fancies himself wise, whilst his wisdom does not teach him to acknowledge a Divine and Infinite Being, that is, he who thinks he can possess any wisdom without a knowledge and veneration of the Deity, has not even a particle of wisdom. The philosopher sees, indeed, that God governs his creation by rules and mechanical laws, and that the soul governs the body in a similar manner; he may even know what those rules and mechanical laws are; but to know the nature of that Infinite Being, from whom, as from their fountain, all things in the world derive their existence and subsistence,—to know, I say, the nature of that Supreme Intelligence with its infinite arcana,—this is an attainment beyond the sphere of his limited capacity. When, therefore, the philosopher has arrived at the end of his studies, even supposing him to have acquired so complete a knowledge of all mundane things that nothing more remains for him to learn, he must there stop; for he can never know the nature of the Infinite Being, of his Supreme Intelligence, Supreme Providence, Supreme Love, Supreme Justice, and other infinite attributes. He will therefore acknowledge that, in respect to this supremely intelligent and wise Being, his knowledge is nothing: he will hence most profoundly venerate Him with the utmost devotion of soul; so that at the mere thought of Him, his whole frame, or membranous and sensitive system, will awfully, yet sweetly tremble, from the inmost to the outermost principles of its being.

As nature is the first beginning of the changes that occur

in the world or mundane system, or as nature is the motive or active force, or collection of forces, by which those changes are occasioned, it follows that the world is dependent on Nature and inseparable from it; and that the world is nothing without Nature, and Nature is nothing without the world. But the Infinite is still Infinite independently of the world; while, on the other hand, no conception can be formed of a world independent of the Infinite. We see then that nature cannot be without the world, but that the Infinite can, and that he may be a Being capable of being separated from the world: we see also that all things were produced by Him, that the world was created by Him, and with the world Nature herself. Nature is only a word which expresses all the motive forces proceeding from the first motion of the Infinite till the world is completed; with this first motion it begins; and as this is produced by the Infinite, so also must nature: they, therefore, are mere children, and have reached scarcely the first threshold of true philosophy, who ascribe to Nature the origin of all things, to the exclusion of the Infinite; or who confound the Infinite and Nature together; when yet the latter is only an effect, a *causate* or thing caused, the Infinite being its efficient and cause. Nature, however, when once produced, may be called the efficient and cause of the world, in so far as all things afterwards successively exist by derivative motive forces and modifications; but it cannot be called the first cause: for no other idea can be conceived of the first motion or mode, than that of an immediate production of the Infinite; whence this mode cannot be called an attribute or the essence of the Infinite; the essence of the Infinite consisting in itself alone: and it cannot be denied that the Infinite existed before the world, (which will be the subject of our second chapter:) neither can this mode be a mode of the Infinite; for no such thing can be said or predicated of the Infinite except by way of eminence: but it is an immediate product from the Infinite. Hence it follows, that Nature, beginning from such motion or mode, is a *causate* and effect.

Now as all nature—the whole mundane system, is the work of God; as all contingent circumstances, before the world was produced and completed, are to be ascribed solely to His wisdom; so also, in case He should be pleased to display by other con-

tingent causes new phenomena, whether foreign and contrary to the nature of our world, or agreeable to it, yet such as cannot be produced by any other active principle than the Deity,—to the same Infinite Wisdom must these also be ascribed. Thus true philosophy leads to the most profound admiration and adoration of the Deity; nor can anything be found to diminish, but infinite things to increase, this admiration: as when a man sees that all things are of the Infinite, and that in respect to the Infinite he himself, as a finite being, is nothing: when also he sees that all his own wisdom and philosophy are, in respect to the divine, in the same proportion as the finite to the Infinite,—that is, as nothing.

Neither does true philosophy detract at all from the credibility of miracles; all things being ascribed to the divine omnipotence, as the origin of the world, and its formation by various contingent means and successive mutations. No contingent mean, tending to the perfection of the world, can exist, which is not a miracle. The world itself is a miracle; whatever exists in any of its kingdoms, whether in the animal, the mineral, or the vegetable, exists by a miracle, because it exists by a contingent mean, which, by a series of others, is terminated in the Infinite itself, as in the first cause of all contingent means. For it cannot be denied that intermediate causes and changes proceed successively from the Supreme Being, who produces all things in the most perfect manner, and conducts them to their destined end. Now what He thus produces by contingent means and causes, cannot be said to be contrary to the order of universal nature, but according to it; and although there should appear some things that are not in conformity with the nature of our world, or not agreeable to the mechanism of our mundane system, yet even in this case they must exist from certain causes, which, like the world itself, derive their origin from the Infinite alone. And relatively to the mechanism of our world, it is a series of mere miracles that could produce one such phenomenon; in like manner when returning to its first origin and cause by contrary contingent means, it would be by a series of mere miracles; that is, supposing our world to remain the same as before the miracle took place. All things which exist in any other world, were they to occur in our own, would be miracles,

as being contrary to its laws of motion—to its order of succession and modification; notwithstanding their being produced according to the order of nature, and being in their own world perfectly natural. In short, if a miracle exists, it exists from the Infinite; if from the Infinite, it exists by means of causes. Miracles may also exist which are agreeable to the mechanism of our world, and others which are contrary to it; but neither can be produced but by some one or other active infinite principle, of which we can form no idea, and, consequently, cannot understand its cause.

But the reader may probably wonder why I affirmed, at the beginning of this chapter, that all our wisdom or true philosophy must be acquired by the use of means; and that the way to reason and things prior is to be opened by experience or *à posteriori*; thus, that our body and external senses are our only teachers and leaders, leaving but little to the mind, from which, nevertheless, as its fountain, all reasoning must proceed, or to which all things must have reference; consequently, that the *animus* of itself, without the use of means, is unable to give any instruction or direction to its body. I will therefore draw a picture of the two states of man; first of his state of integrity, which was most perfect, and then of that perverted and imperfect state, in which, as degenerate mortals, we live at this day. From such a comparison it will probably appear, that it is only by the use of the means above mentioned that the way to the most subtile active principle of our nature can be opened, and that this way must be prepared by mere experiments.

To begin, then, with man in his state of integrity and complete perfection. In such a man we may conceive to have existed such a complete contiguity throughout the parts of his system, that every motion proceeding with a free course from his grosser parts or principles, could arrive, through an uninterrupted connexion, at his most subtile substance or active principle, there being nothing in the way which could cause the least obstruction. Such a man may be compared to the world itself, in which all things are contiguous from the sun to the bottom of our atmosphere: thus the solar rays proceed with an uninterrupted course, and almost instantaneously, by means of the contiguity of the more subtile or grosser elements through

which they pass, through the ether into the air, till they arrive at the eye and operate upon it, by virtue of such connexion, as if they were present; for contiguity occasions the appearance of presence. When, therefore, the most subtile active principle of man, by the providence of God, clothed itself with a body, and added, by degrees, parts upon parts, all the motions in the most subtile elements which were present would necessarily move or affect that most yielding and tender substance, and would gradually impress themselves and their own mechanism upon it. So also would the motions in the grosser elements, such as the air; for the air, always moving and undulating around it, and perpetually acting upon the same substance, would also form to itself something similar, and, by its continual motion, cause itself, as in the case of the other elements, to be received within. The like would occur in regard to whatever was fluent in the air with a more unequal motion, for the atmosphere is always stored with the effluvium of vegetables, &c.; this, therefore, by its continual contact, would form its own mechanism in the sense of smell. In a word, during the growth of the tender parts possessing motion and life, every motion that was perpetually present must necessarily have left vestiges of itself, and must consequently have naturally formed its own mechanism, so as afterwards to be received still more interiorly, but in the same manner as in the yet tender substances. The man thus formed, in whom all the parts conspired to receive the motions of all the elements, and to convey them successively, when received, through a contiguous medium, to the most subtile active principle, must be deemed the most perfect and the first of all men, being one in whom the connexion of ends and means is continuous and unbroken. Such a most perfect material and acting being would in a short time acquire, by the aid of the senses alone, all the philosophy and experimental science natural to him: for whatever could present itself to his senses, would immediately flow, by connexion and contiguity, to his most subtile and active first principle. Thus whatever presented itself to the eye would immediately flow, through the little membranes put in motion by its undulations, to those successively more subtile, till it arrived at the most subtile principle. The case would be the same with motions occurring

in the ear, smell, and taste; which phenomena would also be most easily transmitted to the most subtile principle, through the medium of the sight, and the harmony of the several senses. As, therefore, the whole man was constructed according to the motions of the elements, and those motions were capable of arriving, without interruption, through a medium so contiguous and tense, at the most subtile active principle,—what conclusion can we draw but that such a man must have enjoyed the most complete, perfect, and distinct faculty of reasoning; that all the mundane system or motions of the elements must have been familiar to him after a little contemplation and custom; that every relation of their motions, being impressed upon all his organs as it were naturally and from his tender infancy, would be felt with perfect regularity from his external parts or senses to his soul; and that the soul, being furnished with such a body, would naturally be so well acquainted with geometry, mechanics, and the mundane system, as to be able to instruct herself without a master, from the simple contemplation of the phenomena of nature and the objects of sense. Such a man would be capable of taking his station as it were in the centre; and surveying from thence the whole circumference of his system at a single glance, he would be able to make himself acquainted with things present, past, and future, from a knowledge of their causes, and of their contingent given or supposed.

Let us now consider the perverted and imperfect state of man, or that into which we are born at this day. In this state we see that no complete knowledge of anything can be acquired without the use of means: we see that nothing can penetrate to the ultimate active principle, or to the soul, except by means of continual experiments, by the assistance of geometry, and by the faculty of reasoning to be thus acquired: we see that the way which leads to this most subtile and intelligent ens is almost entirely closed, and capable of being opened only by continual cultivation and exercise, that is, by perpetual experiments and the practice of philosophizing, and by the faculty of reasoning thence acquired: we see that even then the way is not, as it was in a state of integrity, so open, as to preclude the necessity of continual experiments and practice, by means

of which, as things constantly present in the memory, all motions or affections may be remitted to the most subtile principles of our organization, and the passages thus kept as it were constantly permeable and open. For the nature of man's state at this day, and its dissimilitude from his former state, is well known; how possessed he is by motions or affections quite foreign to rationality; how continually agitated thereby are his organs; how his interior texture has suffered violence from different vices, by which the connexion between his more subtile and grosser principles is drawn asunder, distorted, and rendered less contiguous than before. What power the emotions or affections of the body, as pleasures and cupidities, have over the fine membranes of his frame, is sufficiently known from experience: for they are able to induce on the fibres, muscles, and nerves, both the more subtile and the more gross, their own emotions or affections. They are able to distort them; their impression appears in the grosser and external coats of the face, since we often see the countenance disfigured by them and totally changed in a moment. What then must be their effect on the meninges and more subtile parts, or on those mediate membranes and fibres through which a motion or affection is gradually transmitted to the most subtile active principle? In these parts are the organs leading to the most subtile principle. If then these are continually disturbed, they are totally disfigured and distorted; consequently, the natural connexion, which before was perfectly regular, is distracted or broken. Now corporeal pleasures, cupidities, desires, and vices of this kind have almost filled the whole man; increasing with time, they pass from practice into habit, and from habit become completely spontaneous, so as to govern the will itself; in other words, cupidities at length take possession of the will, and withdraw it from the governance of the reasoning soul, so that man at length is capable of scarcely any voluntary action but what proceeds from these emotions and desires, and is frequently without the consciousness of his rational principle. When the will is thus agitated by innumerable allurements and blandishments almost wholly of this description, the consequence is, that it arranges all the organs that mediate between the body and the mind [*animus*], with their series and contex-

ture, into the similitude of its own emotions, or into the effigy of itself; and when their contexture is thus rendered wholly obsequious to the seductions of the senses, it can no longer be inclined and moved, by the mind, except with difficulty and imperfectly. Such an organization, acquired by the indulgence of pleasures and depraved emotions or appetites, is also left by the parent as an inheritance to his children: for we often see children resemble their parents in their countenance and external form, and it is equally common to observe in them a similarity of mind, that is, a disposition more prone to certain cupidities than to others. Children, therefore, are also born and formed after the interior countenance and image of their parents; and thus the whole assemblage of the organs that mediate between the outward man and the mind, is, from its rudiments, or from the womb and the cradle, fashioned after that of the parents, tarnished with the same stains, replete with the same corruption, and rendered naturally, and as it were radically disobedient and unadapted to, the most subtile modes or modifications, and tremors or vibrations of the mind [*animi*], and hence slow to receive them. As then these disorderly emotions of the body have occupied almost the whole man, and have also taken possession of the meninges, in which the mediate motions take place, it is no wonder that at this day the faculty of reasoning is only to be acquired by the use of means, and that it is not possible to arrive by reasoning at the most subtile substance or principle, without the aid of analytical rules, to be taught us by a master, similar to those of geometry. These corporeal emotions and vices, which seem to have done such injury to the mediating organs, are not unlike those dense and dark clouds, which, interposing between the sun and the eye, deprive it of the use of light; though some rays still penetrate through the cloud, not in regular order, but with confused refraction; hence, when the sky is thus overcast, we are deprived of the natural contiguity of the radiant particles, and are unable to discern the azure firmament and the sun itself. Such a cloud, as it always overshadows our little heaven, so it can be dissipated only by proper means; but as some traces of it, either inherited or acquired, will always remain, so must our use of the means for its dispersion be indefatigable and constant. That vices and cupidities

only disturb, but also destroy, the natural connexion of the organs and modifications that lead to the reasoning faculty of the soul, may be illustrated by example. Anger and an intemperate heat of the body so dissolve this connexion, as to render a man wholly incapable of reasoning, insane, and more like an animal than a rational being. Look at the effects of intoxication! How it takes away from the soul all use of reason,—all power of analysis! Thus the connexion is broken, so that nothing but a confused object is presented by the organs; no difference is discerned between things like and unlike; but all, both similar and dissimilar, rush on with the activity given them in one confused medley to the soul. The case is similar with all the passions, when they exceed the bounds of moderation.

I have affirmed that, in his state of integrity, man was master of all philosophy, or mundane science, and this too of himself, by virtue of the perfect mechanism of his organization, that is, by nature; and that, being furnished with such excellent senses, nothing could be concealed from him, because he was formed according to all the motions and operations of the world and nature. I have said further, that nothing could exist in the world from the regular connexion of causes, which would not instantly flow, as through a most clear and pellucid medium, with a certain sensation, to the mind: that is, that all the sensations of each of his organs would penetrate to their most subtile principle, without retardation, confusion, or obscurity. But when every modification in the world, of whatsoever nature, had thus arrived at its ultimate, or at his soul, it necessarily follows that his knowledge and attainments would there stop, and that he would regard and venerate, with a most profound admiration, those other and infinite things that exceeded the bounds of his intelligence; that is to say, that most vast Infinite,—infinitely intelligent, infinitely provident,—which begins where man, and his finite faculties, intelligence, and providence, terminate: he would see that in this Infinite all things have their being, and that from it all things have their existence. As, therefore, all his sensations thus necessarily penetrated to their ultimate seat without any intervening obstacle, and there subsided into a most profound veneration, it follows that this per-

fect man's veneration of the Deity was of equal extent with his wisdom, and as constant as the operation of his senses; we may therefore conclude, that the more profound is any man's wisdom, the more profound will be his veneration of the Deity. No one, also, could be better acquainted than that first and wisest of men with the infinite grace of the Deity: whence it follows, in the same manner, that the Deity must also have been the supreme object of his love; for when we greatly respect any one, acknowledging at the same time the benefits and favours received from him, especially when we are intimately connected with him, we are secretly impelled also to love him: we may therefore conclude again, that the wiser a man is, the greater are his veneration and love of the Deity. Primevally his delights wholly terminated in the love of God,—a love which exhausts and replenishes all sense of delight. All the delights of the world, resulting from its variety, are nothing unless the mind also partakes of them; for no human delights, or such as are proper to man, can be real, without the participation of the soul, since they are destitute of the more refined delightsomeness: and the delights which the body and soul are capable of enjoying together, are not genuine and true unless they have some further connexion, and terminate in the veneration and love of God, that is, unless they have reference to this love and ultimate end, in a connexion with which the sense of delight most essentially consists. It may therefore be most reasonably inferred, that the delights of the first man consisted in this; that the end of the delights which he derived from the contemplation of a world so perfect and pleasing, and from the agreeable perception, by means of his senses and organs, of the motions existing in all the elements, was the love of the Deity. Supreme veneration and supreme love of the Deity could not exist without the supreme worship of Him. What we venerate and love, this we worship; for the utmost degree of veneration conjoined with love must needs be active and operative, and must extend to the will and actions. As no other desires occupied the whole man when in such a state, no others could influence his will; for the will is guided by the inclinations and desires of the soul and body: neither could he induce anything into the will, nor could the will bring anything into act, but what was applicable

to the supreme adoration of the Deity, and to the giving Him thanks full of veneration and love: for these are the delights to which the man who was master of himself and of all his delights and desires would wholly devote and apply himself. For what could be more delightful and voluntary, in such a state of mind, than to ascribe perpetual honours to a Being, supreme, incomprehensible, and so closely bound to him by love,—to pay to Him unceasing vows, to worship Him with constant praise, secure always of His favour and acceptance! We therefore conclude again, that the wiser a man is, the more will he be a worshipper of the Deity. From the same reasoning it follows, that such a man must have been the object of God's supreme love; for love is not only reciprocal, and according to connexion, but is also greater in its prior degree, and becomes less in the derivative.

But the contrary to all this must necessarily take place in a man not in a state of integrity, and in whom the connexion above mentioned is disrupted. Such a man has not the wisdom, the veneration and adoration of the Deity we have described: and as his knowledge of the Divine benefits and grace is also imperfect in proportion to his deficiency in wisdom, so neither can he have such love: in a word, he cannot have any such veneration, adoration, and love of the Deity, as was entertained by the wise first man, unless he receives them from another source, that is, immediately from grace. But whatever veneration, worship, and love, may exist in a man so changed, and in whom the connexion is broken by vices and cupidities, they can never be unaccompanied by fear, because he never can be without cause of fear. Neither can love be supposed to exist in God towards man, after the connexion is broken, but, instead of love, justice. Man's having cause for fear implies justice in God. It is therefore agreeable to reason to conclude, that there would have been no love in God towards man in his unconnected and discontinuous state, but only justice, had not the Infinite and Only Begotten for this cause been made man, that in Himself as a man, and consequently through a certain connexion with Himself, He might restore a connexion with the Infinite in those who are like Him.

CHAPTER II.

A PHILOSOPHICAL ARGUMENT CONCERNING THE FIRST SIMPLE FROM WHICH THE WORLD, WITH ITS NATURAL THINGS, ORIGINATED; THAT IS, CONCERNING THE FIRST NATURAL POINT, AND ITS EXISTENCE FROM THE INFINITE.

1. No rational and intelligent philosopher can deny that the first *ens* was produced from the Infinite, as well as the rest in succession, or all the parts of which the world is composed. For the world cannot derive its being from itself, because it is finite, and consists of parts: neither can these parts derive their being from themselves, because these also are finite, and consist of their parts: nor again can these latter, for the same reason. In short, nothing that is finite can exist from itself, that is, without a cause to bring it into existence. There must also be a cause why it was finited in this or that manner, and in no other; or why it acquired one particular limit, in preference to another. In other words, nothing can exist without a cause, except the Infinite. The Infinite alone exists without a cause, or from itself; nor does it consist of parts. Thus the ultimate cause of things terminates or begins in the Infinite, that is, in Him who exists of Himself, and who consists not of parts; so that from Him finite things must of necessity have proceeded. What is finite, therefore, takes its origin from what is infinite, as an effect from its cause, and as a thing limited from what is in itself unlimited, yet having the power to limit all other things. Whatsoever of a finite nature was produced, could not be finited by itself; nothing finite can exist by itself, because it must needs be finited before it exist; and if so, it must be finited by

something else: whence it follows, that a finite must necessarily exist by that which has the power of finiting it, and which of itself is infinite. In a word, that the first ens, as also all other entities in successive derivation from it, of which the world is composed, and by which it is connected together, were produced by and from the Infinite, is most evident from rational philosophy, from the light of nature and the intelligent soul, as well as from the Sacred Scriptures.

Rational philosophy itself acknowledges a certain connexion and succession, as well in the original existence of things as in their subsistence; nor can it terminate its idea concerning the existence, succession, and series of things, except in what is simple and unlimited, or in that which may be said to have only one limit. With respect to the existence of things, sound philosophy teaches us, that things which are much compounded take their origin from things less compounded; the less compounded from such as are still less so; these from their individual substances or parts, which are least of all compounded, or least of all limited; and these again from things simple, in which no limits can be supposed, except one; from which circumstance also they are called simples. But whence is this simple, in which only one limit is to be conceived? And whence that limit? It cannot exist by itself; for there must be something by which it may exist, if it have a limit, if it be simple, or if it be capable of giving origin to two or more limits. Extending the inquiry, therefore, by the same philosophy we rationally proceed to the conclusion, that such a simple derives its existence from the Infinite; but that the Infinite exists of itself. Again, if we contemplate the successive progression of causes, it will be found highly reasonable to conclude, that nothing finite can exist without a cause; that things which are much compounded, or which consist of many individual parts, neither could be compounded, nor can subsist, without a cause, by which they were compounded, and by which they may consist: for a cause always precedes, and afterwards accompanies that which exists from it. The individual parts of such a composite must in like manner be compounded of, and subsist from, their individual parts still smaller; and these again, by the order of their succession, from things simple: but still things simple

can neither exist or subsist from themselves. Wherefore there must be an infinite something; there must be something infinitely intelligent, which may be considered both as a cause in itself, and at the same time as an operator of effects out of itself; or as an inherent force, and at the same time as a positive agent; or as a power capable of producing, and at the same time as actually producing, the existence of other things. It follows, therefore, that things composite derive their origin from things simple; things simple from the Infinite; and the Infinite from itself, as being the sole cause of itself and of all things.

It was before observed, that all finite things came into existence successively: for nothing can be at once such as it is capable of becoming, except the Infinite. Everything finite acknowledges, or is indebted to, a certain mode, by which it is what it is, and nothing else; a mode, by which it is of such a figure, and no other; a mode, by which it occupies such a space, and no other. In a word, all finite things are modified; and therefore they acknowledge a mode prior to their modification, and according to which it takes place: they acknowledge also a time, in which they were so modified. Hence nothing is at once what it is capable of becoming, except the Infinite. All finite things must necessarily undergo different states successively: but not so the Infinite. And thus we perceive, that all things out of the Infinite have their modification, but that in the Infinite there is no such thing as a mode; He being the original cause of all modifications. Hence also it follows, if nature consist in the modification of things, that the Infinite is the origin and the author of nature.

Thus does rational philosophy acknowledge some first ens produced from the Infinite, and some simple as the origin of entities not simple. This first ens, or this simple, we here call the Natural Point.

2. *Geometry itself also acknowledges a certain simple and first ens of its existence; which it calls its own or mathematical point.* Geometry acknowledges that there is a certain simple point, because it is incapable of finiting it either by figure or by space. Hence it pronounces it to be without extension, and incapable of division; and yet of such a nature, that by its fluxion lines, areas and bodies, may be produced; that by its

fluxion, and multiplication into itself, space may at length be filled; and that by its fluxion degrees and moments exist, whereby composites may be finited and limited. In a word, geometricians ascribe the origin of all their figures and bodies to such a point, yet not as belonging to the science itself, because that is incapable of defining it in a geometrical manner. Thus geometry seeks for its origin out of itself: deriving this point not from itself, but from rational philosophy. Now since the world consists of mere finites, and since it is subject to the laws of geometry and mechanism, therefore, like all finite and geometrical things, it acknowledges its origin to be in a point, which is the same as the natural point of which we are now treating.

3. The Holy Scriptures themselves also give us plain information on this subject, and teach us that the world was created by God, or by the Infinite; that it was created successively; that it was created in time; and that the Infinite is an Ens in itself, that it is an Esse which is, that it is all in all, that it is universal; and further, that it is allowable to contemplate it *à posteriori*, or from effects; but not *à priori*, or from reason. And whatever is confirmed by Holy Scripture, is in no need of confirmation from reason, from rational philosophy, or from geometry; this being already sufficiently implied in the fact of confirmation by the Infinite Himself.

4. Rational philosophy will not admit that anything can be or exist without a mode; and since a mode in things limited and finited, or in things physical, consists solely in the variation of limits, it therefore follows that nothing can exist without motion. Whatever is void of motion, remains just as it is: that which is in a quiescent state, produces nothing: whatever is to be produced, must be produced by a mode or by motion: whatever is to undergo a change, must be changed by a mode, or by motion: whatever contingency is to exist, must exist by a mode, that is, in physics by motion: for without motion or change of place, or to speak more generally, without a change of state, no new existence, no production, no contingency can be conceived; in other words, nothing is capable either of existence or of change, except by means of motion. It follows, therefore, that this first simple ens, or point, was produced by motion: and

since everything is derived from the Infinite, it follows also that this natural point, or simple ens, was produced by motion from the Infinite.

5. If then it be admitted that the first simple was produced by motion from the Infinite, we are at the same time bound to suppose, that in the producing cause there was something of a will* that it should be produced; something of an active quality, which produced it; and something of an intelligent nature, determining that it should be produced in such a manner and in no other, or in one mode in preference to another; in a word, something infinitely intelligent, infinitely provident, infinitely active, and infinitely productive. Hence this first point could not exist by chance, nor by itself, but by something which exists by itself; in which something there must also be a kind of will, an agency, and an intelligence, to produce the effect in one mode rather than in another. There must likewise be something of a provident design, that the effect produced should be successively modified in a given series; and that, by means of a series of modifications, certain specific contingencies should take place, rather than others. All these must of necessity have been in some sort present in this first mode and motion: for in respect to this single and primitive motion of the Infinite, things future and contingent can be considered in no other light than as actually present and already in existence.

6. Since therefore we have traced the origin of the simple, or first point, to the Infinite, from which it is derived by means of motion, we are now at liberty to define it in the following terms:—That it is a simple ens, and the first, existing from the Infinite by means of motion; and thus that, in respect to existence, it is a kind of medium between what is infinite and what is finite.

We shall now proceed to consider and explain, distinctly and particularly, whatever concerns the origin of the first point, together with its attributes and essential properties.

7. Let us return, for a few moments, to the consideration of the positions already advanced. With respect to the essential of the first simple, I maintain, that this natural point is the

* Aliquid velle.

same as the mathematical point, or the Point of Zeno. For the world is geometrical or mechanical: nature modifies itself by the laws of mechanism, which are its own laws: wherefore the same beginning is to be assigned to the world, as to geometry: the same point is the first of the world, because it is the first of geometry; or it is the first of geometry, because it is the first of the world. Geometry is the law and essential attribute of every individual substance in the world, or of the whole world; and mechanism is the mode, by which the world acts or is acted upon: hence the point is common to both, because both flow from the same origin. Thus each acknowledges a certain ens before itself, and out of itself, which it considers as a kind of seed, from which it was conceived, and by which it afterwards exists and subsists. Since therefore both geometry and the world are derived from the same origin, the same seed, and the same parent, we must conclude that they both proceed from the same point; the difference consisting in this, that the latter point, or that of the world, is called the natural point, while the former, or that of geometry, is called the mathematical point.

8. *That this point is a simple ens, and indeed so very simple, that nothing can be more so, because what is simple admits of no degrees.* The Infinite itself, in a geometrical point of view, may be called an Ens, yet only in an eminent sense: but that which first exists by motion from the Infinite, becomes an ens in consequence of its essence consisting in motion. It cannot be said of the Infinite that it is the first simple; for there is a great difference between what is infinite and what is simple; the one being considered as the cause, while the other is only the effect. That which is simple, as having one limit, cannot be the cause of itself, but must acknowledge its cause to be in another, which has no limit, and which is the cause of itself. Therefore, if they be distinct in themselves, the one must of necessity be prior to the other. Neither can the same thing be predicated of the Infinite, which may of the simple; nor the same of the simple, which may of the Infinite: wherefore this first product of the Infinite must be that simple ens, which is to be acknowledged as the first simple of things finited, and as the cause of the first limit or boundary among such finites. Nor

can it be a finited simple; for this must consist of two boundaries at least, without which it cannot have the name of a finite: but this subject will be more fully discussed in our next chapter.* That it is therefore a simple, appears from these considerations, that nothing can exist in a more simple state than that which primarily and immediately proceeds from the Infinite, and which first exists in the Infinite, prior to the possibility of its existing in any finite, or among things finited; also that it is the origin of the first boundary of the finites, from which all others are afterwards derived. Now since composites acknowledge their origin to be in some simple, and since nothing can exist of a more simple character than the point of which we are now treating, we conclude, as well from the consideration of its existence from the Infinite, as from the existence of things finited by it, and also from the nature of the thing regarded in itself, that this point must be a simple ens.

It follows, therefore, that it is in no respect compounded, nor finited, nor limited, because it is simple; with this exception, however, that it may be said to have only one termination or limit. Since it cannot be denied, that a simple ens ought to be considered as the origin of entities not simple; that one limit must have a being, before two limits can exist; one boundary before several; it must also be admitted, that a ratio between such boundaries first takes place, when one is succeeded by another. But if that one which precedes another be finited, and if it contain within itself several smaller boundaries; it follows, that the last ratio neither is nor can be given, except in that which has one limit only, and that it exists before the first substantial or finited boundary. When therefore two things are found to exist, there must be one; when several limits are given, there must be one limit: in short, according to every reason of the case, wherever there is a finite, there must be something not finited; wherever there is a composite there must be a simple; wherever there is a body, there must be a point as the origin of that body: and since such a point must exist, before there can be limits, boundaries, and a body, it

* Chap. iii.; prop. 9.

may hence also be said to possess one limit. Nevertheless this point has in itself something analogous and similar to what exists in things limited, inasmuch as it consists in motion; and although pure motion does not necessarily require anything substantial as the basis of its existence, there still adhere to it both figure and space, which are attributes of motion. And thus it appears, that there must be a certain relation of figure or space to the motion of this point; something in the motion of analogy and similarity to it: the whole analogue or rational simple, being what constitutes the point.

9. *Since this point is only one limit, it follows, that it is the first ens and seed of things finited.* The Infinite cannot be said to be the first ens and seed of things finited, except so far as it is their cause, and the efficient power to bring them forth: such a first ens requires to be produced from the Infinite, in order to be of the character here intended. Every seed must acknowledge its author, its producer, or cause of its production; for it cannot be self-produced: it must therefore acknowledge Him to be its author, who exists of himself. Hence, as before observed, the Infinite cannot be said to be the first seed of things finited, except so far as it is the cause and efficient producer of such a simple ens, or so far as something of infinity is admitted to enter into the pure motion of this simple ens.

10. *Nevertheless this point is a kind of medium between what is infinite and what is finite;* for it is through the medium or intervention of this point, that things finite exist from the Infinite. This point is a medium both as to existence and as to origin; for it first originates from the Infinite, and then gives origin to things finite. On the one hand it acknowledges the Infinite, and on the other the finite; thus it stands between the two, and looks as it were both ways, having respect as well to the immense Infinite, as to the immense finite; and in reference to its existence, may be said to participate of the nature of both. It may be compared to Janus with two faces, who looks two ways at once, or at each universe. On one side is the pure Infinite, into which no human mind is able to penetrate, or in which it cannot discover either a least or a greatest, both being completely unknown, and of themselves identical:

on the other side is the mere finite, to which we may have access, through the medium of this point, which as to its existence partakes in a manner of the nature of both. By this point, as by a door, we are introduced into the world; and admitted into a kind of geometrical field, where ample scope is afforded for the exercise of the human understanding. As soon as, through the medium of this point, an entrance is found, into the finited universe or the world, man instantly begins to have a knowledge of himself, to perceive that he is something, that he is finited, mechanical, nay, even a machine: in other words, by this point we are introduced into the world, and into its law, that is, into geometry, which could have no existence prior to the existence of the point. Nature itself also commences with this same point: to this it is indebted for its birth, that is, for its conception and exclusion as from the womb; and from this it first receives what may be called its life, and its forces under their several modifications. Wherefore the world is incipient at this point, and with the world nature itself; or, what amounts to the same, nature has its incipience by it, and the world with nature. On these grounds and considerations, our point may be said to be the medium between what is infinite and what is finite.

11. *This point is produced immediately from the Infinite.* With respect to existence, as was before observed, one precedes the other; with respect to cause, one is the cause of the other; with respect to mode, one modifies the other, this other not being capable of existing without a mode; and with respect to subsistence, one subsists from the other. Now in relation to existence, it is evident from the light of reason, that the Infinite must have existed before the point; in relation to the cause, that the Infinite must have been the sole cause of motion in the simple or in the point; in relation to mode, that the Infinite, by means of motion, must have produced the first simple or the point; and in relation to subsistence, that all finite things, produced in the way here described, do actually subsist from the same cause and mode which brought them into existence. Since therefore the Infinite in respect to existence precedes, it follows, that as an antecedent power it might have existed, and might still exist, without such motion as that above supposed: and since it

was the cause of motion, it follows also, that it was in its power either to be, or not to be, the cause of such and such a particular effect. The same conclusion likewise results from the consideration, that motion is the mode by which the point existed; and moreover, in the Infinite there can be no such thing as mode, unless indeed the contemplation and will that something should exist by a mode may be so called. Wherefore, since all finite things, which exist by such a cause and mode, are in their nature distinct from the Infinite, it follows, that the first motion, which is the essence of the point, is immediately produced from the Infinite. We cannot say that the essence of the Infinite consists in motion; motion being rather the offspring and production of the Infinite, and indeed its immediate production; unless perhaps we indulge in an idea, which nevertheless is evidently above the sphere of reason, that the motion, which takes place in the point thus immediately existing from its source, is afterwards inseparable from the Infinite, because there is motion in the universal Infinite; in which case we may infer, that such motion, although it be not the essence of the Infinite, is yet not inconsistent with its essence, because it has its existence in the manner described.

12. *This natural point is purely motion in the universal Infinite; and consequently it is pure and total motion, a motion which cannot be conceived of according to any laws of geometry.* When we lay down the position, that the first motion exists in the Infinite, it is absolutely necessary that such motion should be considered as pure and total; there being nothing which is capable of finiting it; nothing, by reason of which it may be said to be mixed; nothing which admits of degrees: so that it cannot be conceived of as celerity. All motion which is mixed, or which is finited by degrees, supposes something substantial, capable of motion or of modification: but the motion of which we are now treating cannot admit of any such thing, because it belongs to the Infinite, and exists in the Infinite: for which reason also, in consideration of its producing cause, the motion must be supposed to be pure, and incomprehensible by the powers of geometry. But as it is not strictly geometrical to say that there can be pure and total motion, when no such motion is found in things geometrical and

finited, a doubt on the subject may possibly present itself to the reader's mind: yet if he will grant, what indeed cannot be denied, that there is an Infinite Ens, and that finite things were produced from the Infinite, what other conclusion can be rationally drawn from these premises, than that a first mode did exist? And if so, reason dictates that it could exist only in the Infinite, and not in any finited medium. Hence, if the Infinite be granted to be a producing cause: and if a mode or motion, as an effect produced, be likewise granted; then it must of necessity also be conceded, that there is a pure and total motion: for that which alone does or can occasion the motion to be not pure, and not total, but mixed, is the mere finite, which, according to our hypothesis, is not yet in existence. Wherefore, since this motion must have existed in the Infinite, and before the birth of finites, it follows, that it must also have existed before the world, and before its established laws, that is, before mechanism and geometry; thus it cannot be viewed geometrically, but rationally. And though we cannot form a true conception of such motion according to the principles of geometry, we are not on that account to conclude that it is nothing; although it bears no respect or analogy to finited motions. A simple ens cannot be conceived of geometrically; yet it is not on that account nothing. The Infinite cannot be conceived of geometrically; yet it is not on that account nothing. A finite, in respect to the simple, is as nothing. A finite, in respect to the Infinite, is nothing, because there is no ratio between what is finite and what is infinite; which is the reason why it is said that what is finite is nothing in respect to the Infinite. Still, however, what is infinite, pure, total, and simple, is not to be esteemed nothing; although respectively it may equal nothing, and thus be incapable of being geometrically conceived or described. Rationally speaking, if there be a composite, there must be a simple; if there be anything extended, there must be something not extended; if there be anything mixed, there must be something pure; if there be a part, there must be a whole: that is to say, if there be a mixed and partial motion, there must be a pure and total motion. Pure motion may therefore exist, but not in space, or in a medium consisting of finites, or among finites.

13. *That this motion presupposes nothing substantial, by which it may be said to exist.* In the Infinite there is nothing substantial, nothing capable of modification, as in finites: but since motion is not inconsistent with the Infinite, the Infinite may be considered not only as the cause and producer of it, but also, by way of eminence, its modifier. Hence, as there is in the Infinite nothing substantial to be modified, no other motion can exist in it than such as is pure.

But since pure motion exists neither geometrically nor mechanically, it must therefore be of such a quality, that neither degrees, nor momenta, nor anything of celerity can be assigned to it; all we can say of it being, that such motion actually exists in the universal Infinite. Yet the Infinite is utterly incomprehensible: hence an idea of this motion as existing in the Infinite becomes still more incomprehensible. For were we to multiply the greatest finite, or the whole world, into the Infinite, nothing would be the result; since no finite, whether considered particularly or generally, bears any the smallest proportion or ratio to the Infinite; but everything finite vanishes by the comparison, or becomes nothing. How then are we to conceive of this purity and totality in motion? Certainly in no other way, if geometrically and rationally understood, than as an internal state, or effort [*conatus*] to motion. For if in the whole motion there be no degrees, no moments, and thus no celerity; and if again there be nothing substantial, as before observed; what else, according to every human notion or idea, can result thence, but effort or *conatus?* When we understand space simply as it is, and consider motion as pure and free from moments, in such case the motion must be instantaneously present in every part of its proper space; and thus it will be like effort or *conatus* itself: for in *conatus* not only is motion everywhere present, but with it also its force, direction, and celerity. This *conatus*, or effort towards motion, may also be called internal state.

But to prevent any confusion or misapprehension in our ideas concerning motion, effort, and state in the simple, which, as hitherto used, appear to be mere terms, entirely abstracted from, and foreign to, every law of geometry, so far as they are said to belong to things simple; we will now endeavour to ex-

plain the subject by means of geometry, figures, and compounded motions, and thus in some measure present to our ideas a determinate or fixed object. For example, let us suppose the parts or minute particles of a body, which are perfectly alike, to be put into motion one among another; and let us further suppose, that the cause of the motion is within each particle; it will hence follow, that by continuing their motion for a sufficient length of time, they will be brought into a situation conformable to the motion and figure of each, when they will begin as it were to link or bind themselves together; and in this state they will be found to be in the situation proper to their peculiar motion, which situation is that of the whole composite body, or its internal state. But the cause of motion, inasmuch as it remains in each individual particle, and no single particle can be moved without all being moved together, hence becomes common, and pervades the whole; so that by reason of it all endeavour, and conspire together to produce one common and unanimous motion: this is what we mean by *conatus*, or *effort*. Thus we have first the motion of each individual particle; then the state of all together, which is the internal state; and hereby effort, or *conatus*. Let us now return to things simple, and see whether by the aid of the motion, state, and conatus in geometrical substances, as just above described, we can form any better conception of the motion, state, and conatus, which take place in things simple. In a simple there are no parts, or individual corpuscles, capable of being put into motion: but since there is in it a cause of motion, as before observed, we must therefore form an idea of motion without parts or individual particles, like an effect from its cause; and this can be conceived of in no other manner than as a pure and total motion. Hence there can result no disposition of parts, nor can any other state take place by means of situation, than such as is inherent in that perpetual motion: consequently, neither can there arise a conatus from any other source, than from motion. It follows, therefore, as motion is destitute of parts, that motion, internal state, and conatus in the simple, may be considered as one and the same thing; when yet in finites they are different from each other, because in these there is a motion of the parts, and consequently a mixed

motion. But if the reader still entertain a doubt, and cannot yet comprehend what motion is without something substantial, or what is meant by pure and total motion in the simple, I would observe, that it is its state: should this appear equally to require explanation, I say, that it is its conatus or effort leading to a certain motion: and if this be not satisfactory, then I add, that it is all these taken together. I cannot give a more clear and full explanation of the interior nature of the simple, unless indeed the following may be so considered, viz.:—That in things subject to geometry there can be no state nor conatus without motion; while in things that are beyond the reach of geometry, that is, in things simple, there can in like manner be neither state nor conatus without motion; yet with this difference, that in things geometrical they are distinct, and one is the cause of the other, while in the simple they are not distinct, but one is coexistent with the other, and all together present one simple mode, and constitute a simple ens.

14. *That this point cannot be conceived as having any extension; that it is without parts, and consequently indivisible.* If there be in the point nothing substantial to be moved; if the motion be pure, not mixed with anything substantial, and not arising from it; or if there be a conatus tending to motion; it follows, that it must be destitute of parts, there being nothing of the kind in such motion or conatus: for parts presuppose the existence of things substantial put into motion, of which they necessarily consist. If the point be without parts, it must also be indivisible; for to divide, would be to annihilate it. In respect to its own motion, it may be said to have a kind of extension: but considering that there is nothing substantial in it, as the subject of motion; that it cannot be divided without annihilation; that it has only one limit, and is thus a simple, it must be pronounced free from expansion. For everything limited originates from something not limited; every thing finited from something not finited, or from a simple; every thing extended from something not extended; just as numbers arise from unity, and unity from what is least in our conception, or next to nothing.

15. *That neither can it be said to fill space, unless it be space simply understood.* If the point be not extended, but of

such a quality as to give origin to extension, it follows also, that it does not occupy space, unless it be space simply understood. For since it possesses only one limit, as being a simple ens, and this one limit includes no space, it cannot, in reference to things finited and variously limited, be said to be a space; but in respect to that pure motion, from which it originates, something of space may be attached to it in idea; yet only in the way of analogy, or proportional attribution.

16. *That the point cannot be said to be endued with figure, unless the figure be simply understood;* and this can only be comprehended by a certain analogy and similitude, which it bears to its own motion within itself. As its space must be simply understood, so likewise must its figure: for of whatever kind be the space, of such is the figure; the quality of the space consisting in the figure. Now since the space must be simply conceived, and considered as a limit or as one boundary to finites, in the same manner also must the figure be conceived; that is, in respect to the figures of finited spaces it must be simply understood. For the largest figures, which we will suppose to be circular, have many or very extended points of contact; smaller figures have fewer or less extended; and the smallest or simple figure may be said to have the smallest points of contact, or such points simply understood; and thus it may be called a simple figure. As for example, let us imagine innumerable circles round one and the same centre; and let radii or diameters be drawn at every angle from the centre through all the circles; the widest circle will then give the greatest degree or arc to the angle; the smaller circles, or those nearer the centre, will give smaller degrees or arcs; and the circle nearest the centre will give the least; but the centre itself will give none. Still however a conception must be formed of its figure, in the way of analogy, and in reference to its conatus or motion: for motion creates space, and consequently figure; motion cannot exist without space and figure; and whatsoever is in motion is present also in conatus. Yet in itself, and in respect to the motion, of which it is composed, something analogous and similar to what exists in things finited must be conceived.

17. *That figure thus conceived is most perfect.* Since conatus may be contemplated after the manner of motion, whatsoever is

in motion being also in conatus; and since there is nothing in motion which did not previously exist, and is in conatus; therefore, instead of the term conatus, we shall in the following pages substitute pure or total motion. Nothing then can be supposed more perfect, than the figure, which is produced from the purest motion, and which exists in the Infinite. And if such figure be most perfect, all entities of a like kind must also bear a full and entire resemblance to it. In the Infinite there is nothing dissimilar to itself; nor is there anything of dissimilitude in pure motion. Dissimilitude is produced by limitation, by the commixture and conjunction of several things; also by multiplication, division, geometry, and the mode or modification of things similar. For the more an ens is modified, so much the more is it rendered dissimilar to another ens; dissimilitude increasing in the things modified by a continual series. Since then this first point is not yet modified, and since it derives its origin from no other source than from the Infinite, and from pure motion, nothing of dissimilitude can be supposed to enter into it; for all dissimilitude, whether of the least or greatest degree, is produced by modes, which multiply in series, and which increase in succession.

18. *That in respect to quantities, or when geometrically considered, this point is as nothing, or becomes a subject of mere imagination.* For although it is the origin of so many and so great finites, yet in things finited and geometrical it will be equal almost to nothing.

19. *That nothing can be ascribed to this point, which is ascribed to a composite, except by way of analogy;* seeing it is the most simple, unmixed, pure, and the first ens. But since it is of such a nature, that it must necessarily be contemplated as immediately proceeding from the Infinite, and yet existing before any finite, and so must be considered as non-geometrical, although it resembles what is geometrical, inasmuch as the latter is produced by it, like always begetting its like; I could wish that some other person, capable of the task, would favor us with a better or more just view of the subject. For my own part, I could willingly give up the further consideration of this first ens, to which something of infinity adheres, and proceed to the finites treated of in the following sections, from which the point will

be found to be more clearly elucidated: but to prevent any interruption in the thread of our principles and arguments, we will for the present continue the enquiry already begun. Let it then be observed, that whatsoever is present in conatus, and does not yet exist in act, cannot be termed geometrical until it so exist: but still in every ens exerting a conatus there is something similar to geometry, and to actual motion.

20. *That in its pure and most perfect motion are contained all those things, as well active as passive, which limit things finite, and continue to do so throughout all their series.* That the essence of the point consists in motion, was observed before, and will presently come to be more fully illustrated. Now since its motion is most perfect in its nature, since it has the power of creating something most nearly resembling itself, and since from this point originate all finite things, therefore it must also of necessity contain whatsoever is finited, and whatsoever exists through a long series of finites, both actively and passively. For since it is the one only ens, which gives existence to finites, there must be included in its very conatus and motion everything that is afterwards modified throughout any series, or that is capable of still further modification, together with all the properties of self-modification, such as we find actually existing in the world. For unless this point or simple ens consisted in a conatus tending to motion, and likewise in motion actually produced, nothing could be conceived to be in it of an efficient, active, and productive nature; there would be no cause in it capable of producing any effect, no active or living power; and yet it is in real actual motion alone, that the cause of all existence lies concealed. If a simple were imagined to be void of all internal motion, it would be a somewhat inert, or a mere atom, of itself altogether passive; nor could anything new ever exist or spring up amongst such inert substances or atoms, unless indeed an extraneous motion were immediately introduced among them, which yet must have its cause in some active ens. For if this simple produce anything, and if it be something active which produces, then there must of necessity be motion, and this motion must be in the point itself; that is to say, there must be, not conatus, but act. If any one were disposed to represent the first simple as destitute of internal motion, he

must in this case stop short at this stage of his proceeding, and finite the whole world in that simple and its atom.

21. We now come to inquire analytically into the nature and quality of the figure of this simple point, and into the nature of its space so far as it has respect to motion. For if there be a conatus tending to motion, there must also be figure, there must be space, and other attributes and essential properties, which, according to the laws of geometry, belong to motion.

Since this motion, in which the point consists, *is a conatus tending to actual motion, or what amounts to the same thing, since it is pure motion,* not existing in any medium of finites, but in the Infinite, *its figure must necessarily be most perfect. Pure motion, or motion in the Infinite, cannot produce anything imperfect, or unequal: but whatsoever is produced by it must be in all respects most uniform and perfect. If the figure of the motion be most perfect, it must necessarily resemble a circular figure,* than which nothing in the nature of finite things can be more perfect. But since the point consists purely of motion, insomuch that this point, and pure motion, and a conatus tending to motion, are one and the same thing, it follows, that motion must exist everywhere in the point. *If the most perfect figure be circular,* then the most perfect figure of the motion above described must be the *perpetually circular;* that is to say, it must proceed from the centre to the periphery, and from the periphery to the centre. If therefore the motion be *perpetually circular,* from the centre to the periphery, and reciprocally from the periphery to the centre, or if it be equally diffused throughout, *it must necessarily be of a spiral figure, which is the most perfect of all figures.* In the spiral there is nothing but what partakes of a certain kind of circular form; and nothing within it is put into motion but what takes a circular direction. The motion proceeds perpetually to a circle. The spiral motion may be said to be infinitely circular; every motion round the centre is a circle; its progression towards the periphery is circular; in a word, its figure is circular in all its dimensions and bearings. Perpetual circulation is the same as a perpetual spiral; hence the most perfect figure of motion, as well in conatus as in act, can be conceived to be no other than the perpetual spiral, winding as it were from the centre to the periphery, and again from

the periphery to the centre; thus it is a perpetual reciprocation and spiral fluxion; which is not only the most perfect of all figures, but at the same time also the most convenient or best adapted to the nature of finite things.

If we suppose the most perfect figure of motion to resemble the perpetual spiral, and the point to be a perpetual conatus tending to the spiral motion, and thus the most perfect and uniform ens; it follows from the similitude, which may be traced between it and things subject to the laws of geometry, that it has a centre, and also peripheries, or a centre with infinitely numerous peripheries. *This motion must therefore have its centre in conatus, and it must have a periphery.* These may be considered as the attributes of a perpetually spiral and reciprocating motion, or of a motion which occupies space from the peripheries to the centre. But since this internal motion in the point and its figure can be understood only in the way of analogy and resemblance with the things which exist in finites, its mechanism will admit of more satisfactory illustration from the finites to be treated of in the sequel.

Seeing then it is a pure motion, without anything substantial to be acted upon, and that it flows into the spiral, or perpetual gyres and circles above described, we cannot conceive that there is in the point any such actual flux and reflux, from the centre to the periphery, and reciprocally from the periphery to the centre, as there is in finites, but only a conatus tending to such motion, and a figure most exactly resembling it. Now as pure and total motion, or conatus, admits of no degrees of celerity, but generates from itself the first degree, moment, and limit in celerity, that is generates celerity not yet produced into act, therefore *it cannot be said, that such motion flows from the centre to the periphery, unless it be understood, that it is in the centre and in the periphery at the same moment, and thus instantaneously present in every part of its space.* Hence, if we would amuse ourselves by a play of words, we might pronounce, in regard to the point, that its motion is in the centre when it is in the periphery, and in the periphery when it is in the centre; thus that it is all centre, and all periphery; or that it consists as it were of perpetual peripheries; and that, with respect to the presence of its motion, the centre and the peri-

phery are in a manner one and the same, both together constituting this point.

But geometry can neither express the conatus tending to this motion, nor describe its figure, except by similitude: it is incapable, as yet, of giving any demonstrations; for while it is within this point, it acknowledges itself to be not yet finited, not yet as it were excluded, or brought forth, in short not yet anything, but only about to become something: and in this state it lies as it were in ovulo till matured; that is, it cannot as yet be analyzed by finite terms or limits, which nevertheless successively arise from this ovum. Since therefore this point can receive no adequate demonstration of itself in the way of geometry, we must have recourse to the principles and axioms of rational philosophy, and instead of the point substitute an ens, and so proceed to its investigation by the attributes proper to such ens. Now if we take a rational view of this metaphysical ens, we shall find it to be of such a nature as to consist of only one limit; it is not properly limited; it is not finited; but it is that from which things limited and compounded are derived; it is a something which cannot be geometrically resolved; it is that, to which, and beyond which, no science can possibly extend. It is simple; and yet, being of a productive nature, it is active, consisting in a conatus tending to motion; which motion, were it to take place, would be pure and total, or the same and everywhere present, as it is in conatus. In this ens lies concealed all that quality which is capable of bringing into act things finite, together with all their modes and contingencies, and even of producing the world itself. Thus, unless motion were in potency and conatus within, the ens would possess no faculty or ability to bring into act those things which are really produced, and which together constitute the world.

22. But while there is merely a conatus tending to motion in the point, we have as yet nothing actual: effort, force [*vis*], and conatus, without motion in act or effect, is like a something inert, passive, and dead; which by means of local motion, or the transition of conatus into act, becomes active, living, and efficient; thus from a mere naked cause it becomes operative in an effect. It is with great propriety therefore that we inquire, what is the nature of that conatus? In other words, into what

kind of motion, or into what figure of motion has such a conatus a tendency to put forth itself, if there be no obstacle in the way? For it is well known, that in conatus there are present both force and determination, direction and celerity, with all the essentials as well as attributes of motion. Wherefore, before anything can be produced, conatus must pass into act, like what is formal into what is real; and consequently the point must so pass with its conatus into motion. Since then total motion, or that which is internal, tends to a figure most perfectly and purely mechanical, that is, to the spiral, we hence obtain an idea of the internal state of the point; by which internal state we perceive the quality of the conatus, as it presses forward into external motion. The real determination and direction of active or local motion is alone owing to the figure by which this conatus exists. It was before observed, that the figure is perpetually spiral, proceeding from the centre to the periphery, and reciprocally from the periphery to the centre; by and according to which figure it is inclined to direct every effort, and as it were to aspire to active and local motion. For if there be a conatus tending to motion, and if a similar quality exist in conatus as in motion, then by virtue of that similitude there must exist figure and space. For example, if there be a conatus tending directly from one extremity to the other, a rectilinear motion will ensue in that direction: but if the conatus, by the figure which it assumes, revolve round a kind of centre, in this case a circular motion will be the result. Not only does the motion receive its determination, but also its direction, from conatus; and thus whatsoever does or can exist in motion, is previously to be found in conatus. The figure therefore in conatus, of which the simple ens consists, agreeably to what has been already advanced, is spiral. From the figure we are now authorized to conclude as to the kind of motion into which the conatus runs. *I say then, from the mechanism and geometry of the internal spiral motion there arises a kind of axillary motion; afterwards a progressive motion of all the spiral circles round their poles; and lastly, from the axillary and progressive motion, if there be full liberty, and no impediment in contact with it, another or local motion in agreement with the former, and indeed tending into perpetual surfaces.* But as these subjects cannot be geome-

trically treated, and still less demonstrated, without having recourse to some finite body or corpuscle, consisting of parts and individual substances; and in which those parts and individual substances are arranged into a situation and spiral figure, like those which the conatus assumes in the point; so by the method here proposed we shall be able to obtain a mechanical and ocular demonstration, that such a situation or disposition of the parts or individual substances begets and produces not only a common axillary motion, but also a progressive motion, conformable to the situation and series of the spiral curves; and in addition to this, provided there be full liberty, and no immediate impediment in the way, a second or local motion, by which the surfaces or external particles receive their figure. As the point consists not of parts, it cannot so well undergo geometrical examination, explanation, investigation, and dissection: we shall therefore proceed to the consideration of finites and actives, in which the mechanism of the same motion will be gradually presented to view. We shall afterwards demonstrate by experience, and likewise by the laws of mechanism, that in the point, or in the conatus of the point, lies concealed the whole power, both active and passive, of mechanically producing, in just order and in regular succession, all finites whatever, or the world at large, as well with respect to its smaller and simple parts, as to its greater and composite. *Geometry, therefore, and mechanism, in relation both to the parts and to the whole of a body, and also in relation to the world itself, consists in this, that the first figure of motion, state, and conatus, is spiral; and that by virtue of such a figure there succeed a motion of the whole composite, or an axillary motion; a motion of its parts, or a progressive motion: and lastly, from or by virtue of these, a local motion. Such is the sum of our whole work and of its principles; and such the cause of all the parts and compositions in our mechanical world.*

23. *As the subject here treated of is the point,* or simple ens of things natural, *we cannot adduce any experience in proof of our theory;* nor confirm our principles by any testimonies partaking of this character. In subjects so extremely minute and simple no experience can come to our aid; no phenomenon, no motion can be apprehended by our senses, until we betake

ourselves to things variously finited and much compounded, and thus to a series of composites mutually connected with each other, which, taken collectively, present a true picture of the world in which we live; and thus exhibit their phenomena in a way adapted to the mechanism and connexion of finite entities, yet not by simple, but by variously compounded motions. On the present occasion, therefore, while enquiring into the nature of the point, nothing in the way of experiment can be produced by which the truth of our principles may be confirmed or tested: we can only observe, *that nature, which is a motive force, has neither the tendency nor the capacity of flowing into any other figure of motion more freely than into the spiral; by which figure also its whole celerity is conveyed with the greatest freedom and facility through all its gradations; and to which, in like manner, it appears to have applied all its mechanical energy and power.*

24. Still, however, it follows from reason and experiment, *that motion is the only medium by which anything new can be produced. Motion itself, which is merely a quality and a mode, and nothing substantial, may yet exhibit something substantial, or the resemblance of what is so, provided there be anything substantial put into motion.* If any small body be moved in the direction of a line or a circle, there is immediately produced by the motion the semblance of a line or a circle; although there is nothing substantial in it, except that small body in the place which it occupies. If the motion were to flow in a spiral figure, or by continual spiral curves cubically from the centre to the peripheries, a body of a round form would then be imagined; and yet there would be nothing substantial in the whole of this space, except the single corpuscle, which makes all that space to be substantial in which it flows, or where it is present. If now the motion be very quick, so that in a moment the body is present in innumerable places, in the same moment all that space becomes substantial, wherever it is present. By motion alone, therefore, something may be produced resembling what is substantial, which cannot be produced without some other medium. Motion itself represents something so multiplied and aggregated; and there would also actually be a multiple or aggregate arising solely from motion, were not moments of

time present in the celerity. If now the moments of celerity were the least imaginable, the least would also be that which would distinguish such a kind of substantiality or modification from a positively substantiated form, owing its existence to an aggregate of small bodies. On this account also geometricians suppose a point to be the origin of geometry: from this point they derive their lines, areas, and solids; but they add also a motion or fluxion of the point or points. They consider a point without motion to be incapable of anything, however small, toward the production of a line, because the point is destitute of length and breadth: but by its motion they can form every dimension of a body. In the differential calculus, or analysis of infinites, they likewise avail themselves of a kind of fluxion; from which they obtain their figures, and the relative proportions of those figures. In a word, it is a natural or physical truth, that things finite are generated by fluxion and motion; without which nothing can exist which is the subject of geometry.

25. Seeing, therefore, that we are now brought to the consideration of finites, and are as it were introduced into the mechanical world, we propose in the ensuing pages to proceed to the exposition and demonstration of our principles in the following order. We shall first explain on what ground, or by what reason of the thing, a posterior finite, ens, or particle, derives its origin from a prior one, whether by motion or by any other mode and contingency. We shall then give a definition of the ens, finite, active, or particle, both in general and in particular terms. We shall also examine in a circumstantial manner, as we did in relation to the point, all the attributes, essential properties, motions, figures, spaces, and other qualities, belonging to that ens. After which we shall take a geometrical view of the subject, and endeavour to see how far we may safely indulge in philosophical reasonings and arguments concerning this ens. Experiment and observation likewise will be adduced, where any are to be found; by which means we shall be able to ascertain whether the truth of experiment do or do not accord with the truth of geometry: for a thing may be geometrically and mechanically true, which yet is not confirmed by experiment. There is a geometrical connexion

of finites even in worlds the most diversified from each other; but still the phenomena do not therefore exist the same in all: for there may be various kinds of geometrical connexions, while only one kind is adapted to the perfection of one and the same world. Lastly, we will shew the connexion of every finite, active, or elementary particle, from its first point and origin; so that it may be evident whether or not ends and means bear a mutual respect to each other and in what manner.

Having no other end in view, and being influenced by no other desire, than to be able to arrive at the knowledge of things by the most simple and genuine method; in order to the successful discovery of truth, I do not see that we are at liberty to pursue any other course, than first of all to lay down our philosophical principles, and then to explain them, particularly in reference to the very small and most minute parts above alluded to; that we may be able to discern the real nature of their figure, motion and other modes and attributes, together with the true cause of their origin and existence. After this we shall subjoin an analysis of the whole, that we may see more clearly whether all the particulars do or do not separately and distinctly quadrate or coincide with each other; that is, whether or not our principles are capable of receiving a fuller evidence and demonstration. We shall then proceed to experiments, or to phenomena, by which Nature in a manner renders herself visible to us, and presents to our view her ultimate figure or external face: hereby we shall be enabled to see whether the principles which were at first considered as theoretical, or the work of imagination, and afterwards found to be geometrically true, be also confirmed by actual experiment. Lastly, we will endeavour to trace the connexion between preceding and subsequent principles when they are thus geometrically and experimentally exhibited before us, in order that we may thereby discover whether anything new be produced which did not previously exist; and also whether all things proceed in successive order geometrically and physically, and thus necessarily from the first ens. If this course and method be pursued in our endeavours to find out the laws of the visible world, it may be fairly presumed that we are treading in those steps which can alone lead to the successful discovery of the arcana of nature.

Yet, should any person perceive in the principles here laid down the smallest disagreement with matter of fact, or with analytical geometry; or should he be able to point out anything imperfect or defective in them; if he will have the kindness to communicate the same to me, I will gratefully acknowledge the favour, and receive his hints with pleasure. For truth is only one; truth is my single end and aim; and if any friend will educe from his treasury of science a more just and true representation of the subjects in hand, his kindness in so doing will be esteemed a most acceptable service. Since then nature can be searched out in this and in no other way; and since we are admitted into its interior recesses by this, and by no other gate; on these grounds I hope for the favourable opinion of the critical reader, who, I trust, is inclined to direct all his attention to this simple ens, and to enter fully into the discussion of the first natural point. But let us proceed in due order with our work; and I have no doubt the subject will, in the following pages, receive additional illustration.

CHAPTER III.

A PHILOSOPHICAL ARGUMENT ON THE FIRST OR SIMPLE FINITE, AND ITS ORIGIN FROM POINTS.

1. SINCE therefore there is interiorly in the point, or in its motion, the very quality or actuality of producing other entities or finites, and indeed, in succession, all those which collectively form the world, it follows, that *from the points or simples, mentioned in the preceding chapter, is produced this simple finite or first substantial:* for this simple finite must derive its origin from points; it cannot derive it from any other source. For it cannot exist from itself: it must exist from other things which are also more simple than itself; and since there exists, as yet, nothing beside a point, it must consequently be produced from points. This I call a simple finite, because it is the first finite. Moreover, it cannot be finited and limited by itself; it must be so by other things in which there is a power [*vis*] of finiting: it must therefore be finited and limited by points. Consequently, it derives its origin from points, which, as we have said, are the only things yet in existence.

2. *Nor can any finite originate from points, except by means of motion among the points.* Without motion nothing is produced. In physics, every mode consists in motion: every contingent is made by a mode or modification: every modification supposes something that is moved. A finite, therefore, must be originated by means of the motion of points one among the other.

3. But the motion among the points must likewise have its cause. Motion cannot exist among the points immediately, and

give rise in this way to anything new. *The cause of motion must be solely in the simple or point itself, that is to say, in the internal motion and state of the point.* We must not, therefore, seek for this cause anywhere but in the point, and in its active force as acquired by its own internal motion or state. The contingent which occasions the points to be put in motion one among the other, and, when put in motion, to produce something new and finited, depends also itself upon the first cause of the existence of the points, and upon the points themselves. The entire cause of motion, therefore, among the points, must be in the verimost point itself. It cannot come from without, for here there is no cause; unless indeed it be one which is in a state of separation; and in this case the cause of motion would require to be considered both as most remote and yet at the same time as immediate.

4. How it is that a spiral motion in a point possesses a faculty and force of this nature, we shall explain in the sequel. At present it is sufficient to observe, that the first or simple finite must derive its existence wholly from points, and indeed from the motion among the points; and that this motion cannot possibly derive its own efficient cause from any other source than the motion and actuality of the very point itself. I would here also observe, *that this new motion or motion of the points one among the other, and their state, must necessarily resemble a pure motion, or the internal state which is in the point; in other words, that this new motion must itself also be spiral;* that the centre and periphery are, as in the point, formed by a reciprocal spiral motion; and that in its finited boundaries it resembles the motion and state in the point, so that like begets like. These observations we have premised with the view of supplying a definition of the simple finite: their truth will be further deduced and demonstrated in the sequel.

5. The simple finite therefore may be defined, as being *the first or simple finited ens deriving its existence from the motion of the points among themselves; and as being thus the first substantial of all the finites.*

The attributes of this finite, as also its essentials, together with its motion, figure, space, and all its other qualities, will be further developed in the sequel.

6. *That this first finite is not only the first substantial, but also the least or smallest,* is evident from this; that it is begotten mediately from the points by motion, and that it is the first among the finites. Hence it is not only a substantial, but also the least substantial; which is one and the same with the first or simple finite. From a pure simple, nothing can come but a first finite; for it is finited by the motion of the simples or points; since motion is the only mean capable of finiting and producing what is substantial. On this subject however we shall treat further in the sequel.

7. *That in the whole world there is no other substantial than this finite.* Composites are indeed substantials: but they consist of parts less than themselves, or of other individuals which are themselves also substantial; and ultimately of this first substantial. So that in every compound, nothing can be truly called substantial, except the least or smallest substantial of which it primitively consists. The one is dependent upon the other for the means of its existence, in order that there may be a continuous connexion of the finites from one end to the other, or a connexion leading by mediates from the first to the ultimate end; for, in regard to existence, such is the connexion of the finites one with the other, that there is nothing in any finite which does not, when compounded, depend by connexion upon its first substantial. Should, therefore, any compounded ens be resolved into its least substance, the result of such a resolution would be this simple finite; from which, in a given order, are successively derived the compositions of all the finites. With regard to their modifications and motions, it is to be observed, that inasmuch as they proceed only from substantials, they also acknowledge their first end to be in the first finite. Neither can accidents or contingents, by means of which modifications exist, refer themselves to any other end, or to any other first thing; inasmuch as they refer to a certain substantial. I call it a substantial; because this finite, being the first, is consequently the first substance. If however we would go farther back, or beyond the finites to the simples, we shall be enabled to infer, in like manner, that there is nothing in any compound beside the simple; for this first substantial may be conceived as being divisible, as it were, into its simples or

into points. We may also be enabled further to argue, that in any compound or simple substantial, there is nothing but the Infinite; inasmuch as with respect to its existence and cause, everything subsists and ends in the Infinite; so that if all first substantials, of which compounds consist, were resolved, there would remain in the universe only simples or points. And were all these points resolved, then, since they cannot be divided or resolved without being annihilated, there would remain only the Infinite, such as it was before the existence of the points. We here speak, however, of the first substantial or first boundary of finites; for this is the all in finites; finites being nothing without it.

8. *That the least substantial is geometrical; that it is limited, but limited in its least or fewest boundaries.* This follows from what has been said, since it is the least finite; being finited or limited in its least boundaries. It follows also, that it is the least geometrical finite. Nothing is geometrical which has not limits; for geometry treats of the variations pertaining to limits, together with the limits themselves. Geometry therefore begins with this first finite; whence this first is likewise the least geometrical finite.

9. *That it fills space, but is the smallest among the finites, or is such that a smaller cannot be assigned.* Since it is limited, it will, among finites, fill space. If there are more boundaries than one, there must, in this case, be a distance from one boundary to another, or a space from one limit to another. This we cannot predicate of a point, which possesses only one limit; unless we predicate it by way of analogy to its internal motion, on which subject we have spoken above.

That it is endowed with figure, but figure in its smallest boundaries. This also follows from what we have said. If there be space, there is also figure. If the space be the least possible, then the figure which the space forms, must be a figure in its least boundaries. For a larger figure has several boundaries, since it is composed of several points before it is bounded; while a smaller figure is bounded by fewer points. The smallest figure, therefore, is bounded by the fewest and least limits, just as the figure of a point, which is the most simple, has only one limit.

10. *That of all finite figures the figure of the first finite is*

the most perfect. In the series of finites there cannot possibly be a more perfect figure than that of the finite which comes proximately from the most simple finites, or from points; which cannot admit into themselves anything but what is most perfect; because they exist immediately from the Infinite. Now if the figure of this finite be the most perfect of all finite figures, then the most perfect figure will be that of the simple. The more compounded are the figures, the greater number of modes and variations must they experience; so that if they undergo several modifications, it follows, when they have become frequently modified, that in their successive degrees of perfection they differ from the first figure immensely. With regard to the figure of this finite, what it is when it is most perfect, we shall endeavour to shew in the sequel.

11. *That the figures of these finites are most perfectly similar one to the other.* One, and indeed the principal, degree and mode of perfection, consists in similitude. Since points or simples are most perfect, in that they are also most exactly similar, because they are produced from the Infinite, from whom nothing but what is most perfectly similar can proceed; and since these finites afterward proceed mediately from these exactly similar points or simples; it may be said, that of all the figures of finites these are the figures which are the most perfectly similar one to another; and although it cannot be denied that some dissimilitude may exist between these finites and between their figures, still the dissimilitude will be the least that exists in the series formed of successive finites. The dissimilitude itself arises from a series in the modifications, or in the frequent variations of the limits. The more frequently limits are varied, the greater number of casualties and causes there may be to produce dissimilitude; whence in things much compounded, there may exist, as it were, an infinite dissimilitude; so that, at length, all the compounds in a series of the same degree or genus may be dissimilar. The nearer however they are to their origin and first limit, that is, the nearer they are to the first similar entity, the first simple, the first and only mode, the less variation can they undergo; because the fewer are the causes of variation and the fewer the contingents and modes.

12. *That this finite derived its origin from the motion of the points among themselves.* Inasmuch as nothing previously existed besides a point and a simple, it necessarily follows, that what immediately succeeds, derives its origin from that which precedes. The reason is, that the existence of things must consist in the successive series of entities, proceeding from the most simple ens to the most highly compounded. According to this law of succession, therefore, this first finite has its origin and is born, from its prior as from its parent. Origination must proceed from motion: without motion nothing can be conceived to originate. It must be motion which finites, and which limits. An aggregate of points cannot be finited or terminated except by motion. There is nothing which gives it any certain limit or boundary beside motion; nor is there anything, besides motion, which distinguishes points, before collecting or when collecting into an aggregate. By the accession of motion not only may such an aggregate receive its own proper and certain limits, but its own proper and certain space, its own proper and certain figure; it may acquire its centre and circumference; in fine, it may acquire boundaries possessing a certain and similar figure, or a figure possessing certain and similar boundaries. Without motion, we could not conceive any formation of a centre and circumference, nor any coherency of the parts or points in this primal, and as yet not even elementary state. It is motion itself which ties and binds all together; which keeps one thing joined and united with another; which determines one to the centre, another to the circumference, and *vice versa;* which confines them, as it were, between certain walls and barriers; a result for which we could not look, were any aggregate, consisting of points or finites, void of motion and thus inert. Whatsoever is without motion must become dissipated [*diffluerel*] of its own accord. Were there no cause of composition, there would be no cause of coherence; that is to say, the compound would be dissolved by the same cause by which it was compounded; particularly in the present case, or in the state in which no element as yet exists to press equally on all sides, and thus make some entities close into a corpuscle or certain separate aggregate; and in which also there is nothing in the entities themselves to make them cohere without an elementary

cause, and to form the limits of a given figure. Not only, therefore, must motion be the only bond of connexion—the only means of composition; but it must be also a most perfectly similar and regular motion, which shall bring the entities into a certain similar, and regular figure.

13. *That the kind* [ratio] *of the motion between the points which forms this finite is in a certain respect similar to that which is in the point itself.* Although the ratio between the internal motion of this finite and the pure motion in a point is one of which we cannot form a conception, it may nevertheless be concluded from analogy, that a motion in a point, and which composes the point itself, is similar to the motion in this finite, or which composes this finite; that is to say, the point is composed by a mean or mode of motion similar to that by which this finite was composed. The similarity consists in this; that, in the point, motion or state is from a centre to a certain given circumference, from this circumference to the centre, and so on continually and reciprocally; so that, in a point, the animation, as it were, or reciprocation of motion, is into a figure similar to that which is in this finite. For since, in the motion of a point, all those things have their inbeing which exist throughout the series of finites successively compounding themselves, even to the most gross or ultimate, such as we see existing in the world; and since a point now ceases to be by itself and begins to be in its sequent or in this first finite; it follows, that the same quality must be in it which we have conceived to be in a point: that is to say, the motion in the finite must be similar to the motion in the point; there must be a similar and reciprocal anhelation from the centre to the circumference, and from the circumference to the centre. In a word, there must be the same kind [*ratio*] of motion and the same state in the finite, which there is in the point; consequently, the same actuality or active force in producing derivatives and propagations from the point into its first finite or first offspring. For the various things which proceed in succession from a point, are themselves mediates to some further end. If anything new derives its existence from a point, then in this new thing there must be the same quality of producing similar mediates. Without this faculty there could be no adequate mediates; and much less could any

other end be obtained. It is in these intermediates that consists the connexion of causes from one end to the other; that is to say, it consists in their production in such a manner that every intermediate is capable of representing one end; and this, by reason of its similitude to that which constitutes the end.

14. *Hence it follows, that this finite possesses in itself the same active force as the point; so that it is able to finite and produce the subsequent and more compounded finites; that is to say, it receives from the point its power* [vis] *of finiting the sequents.* For if there be a connexion of causes extending from the first simple to the ultimate compound, there must be the same actuality in the sequent compound as in the first simple: I mean the same actuality or active power of producing sequents. For when the more simple and antecedent entities become evanescent, in consequence of entering into the composition of the present sequent, then this sequent becomes, as it were, the first end, or one ultimate end of the subsequents, for the antecedent has no longer any subsistence except in the composition of the sequent, so that in our nascent world there is now no simple or point, but only a finite or first substantial. This finite therefore becomes, as it were, the end of the following finites; although, in respect to the point which preëxisted, it is only an intermediate. If therefore this new finite, emerging or existing from simples, be, as it were, the new end of the sequents, then there must be in this finite the same quality and actuality of producing sequents as there was in the point of producing this finite. Thus have we the essence of the point derived into this finite; and the very same primitive and latent power [*vis*] of actuating that was in the point, translated into this finite, and at the same time receiving a fresh limit.

15. *That the first finite thus possesses an internal motion equally with the point.* In internal motion alone consist the power [*vis*] and quality of producing sequents into act; and were the first finite destitute of this motion, it would possess no force or power, and would always remain inert; neither would it in this case produce anything in addition to itself; unless we suppose there came to it a force from some other quarter; that is to say, unless there came a motion from some cause extrinsical to the finite. But if this motion came from

some external cause, the new production would not emerge from the point or the finite, but from some other origin which was always able to give motion to inert things, and which would modify itself in accordance with that series: and these causes proceeding from this other and new origin, must likewise have such a connexion one with the other, as to be able to put every one of its compounds in motion. Inasmuch, however, as any one thing which produces any other into act, or inasmuch as every cause, must, together with its concatenation of other causes, lie in one and the same ovum and in the same point, so in every instance in which we say that a thing is successively produced, it follows, that a cause and a train of causes cannot consist in anything else than in the quality of the motion in the first point, derived into the successive finites continuously by similitude; that is to say, they must consist in a motion which continually follows and successively accompanies every finite; consequently they must consist in the internal motion and situation of the parts.

16. *That this simple finite must be compounded by means of a motion among the points; and that the points ultimately settle into a site conformable to their motion and figure; consequently, that the site thus formed in motion derives its similarity, as also its quality and power of thus moving itself still further, from the motion, figure, and space of the points.* If the motion, internal state, and conatus in the point be the same; and if the conatus (in case nothing hinders) pass into an act and motion suited to itself or to its internal state, or if it present itself as active; then there is immediately an active force among the points which is reciprocal, or in virtue of which one acts upon the other. This being granted, there is a reciprocal action among the points; an action which consequently terminates in a site or situation conformable both to their motion and figure. Inasmuch, however, as the points are in perpetual motion when disposing themselves into this situation, the situation must be one which is conformable to the motion, and the end of the motion must be similar to its intermediates and causes. Nevertheless, because in this site there remains an active force in every point, so long as the internal state remains; and because, in the motion, this site is so formed as to be suited to the motion,

it follows that no other disposition of the parts can result, than such as will admit of a quality and power of moving themselves still further, and as much as the figure of the parts will permit. Any body, when put into motion, if there be other bodies collaterally in motion with it, must necessarily tend to an equilibrium; but does not arrive at it until it comes into a situation conformable to the motion, figure, and space of its parts.

17. *That this finite is, in regard to its substance, the first boundary of all the other finites; that in regard to its motion, it is the first ratio of their celerity, and that the analogies between finites cannot be reduced to any smaller boundary and ratio.* For since, in regard to its substance, it is the first and least substantial, it must consequently be the first boundary of all the finites. A point cannot be called the first boundary, because it is not finited. And inasmuch as the first boundary among finites must be finited and substantial, it follows, that this finite deserves to be called the first boundary of the finites; and, consequently, that no proportions or analogies between finites can be reduced to a smaller boundary. In like manner it follows, that the motion of this finite is the first ratio of celerity.*

18. *That in relation to things much finited and compounded, this finite is as it were nothing; that nevertheless it is a something and a finited ens.* Since it is a least substantial, a less than which cannot be assigned, it must necessarily be such as, in regard to things much compounded, must almost vanish, as being nearly equal to nothing. Still however it is a something, and the first boundary of all the finites. For if this finite be the proximate to the simple, it must be proximate to such as, in a geometrical sense, the most nearly approaches to nothing.

19. Hitherto we have treated of this subject abstractedly and philosophically; we now come to treat geometrically of the figure and motion of the points constituting our first and least finite. Although we can as yet scarcely treat of it even geometrically, since it is a geometrical minimal; and nothing is as yet extant with which it can be analytically compared, and thus to which any analogy can be found. From a first and only boundary no ratio can be educed; for a ratio requires two things. Inasmuch, however, as our finite is finited and limited,

* Or first kind of velocity.

we may conceive geometrically of some ratio between its ultimate boundaries, or those with which it is terminated. We may also conceive of some ratio in regard to the motion of which our finite has been said to consist.

From a variety of reasons it may be concluded *à priori*, that the motion and relative situation of the points thence arising, is similar to the internal motion and state of the point; or, that it is a spiral reciprocating from the centre to the circumference and from the circumference to the centre. For if every thing which exists in the finite be most perfectly finited, because it proceeds from a most perfect simple, it follows that the figure of its motion must be most perfect. If this figure be most perfect, it must be circular; since there is no figure more perfect than the circle; for a circular figure has no termination, no end, no angle; its termination, end, and angle, being everywhere the same, similar, and consequently one; in which respect it has a certain relation to infinite perfection. If, therefore, the figure of the motion is the most perfect, we cannot conceive of any which is more perfect than the circular, or more nearly approximating to what is most simple, or to the Infinite. If, however, the figure be the merely circular, it cannot be the most perfect, unless it be the perpetually circular; circular in every point of view, and in every dimension; namely, from the centre to the circumference, from the circumference to the centre, and so on in continual and perpetual reciprocation. Such a circular figure is presented to us only in the spiral, which flows by continual circles from the centre to the circumferences. For in a spiral there are perpetual circles; there are circumferences at every distance from the centre; it runs in a circular direction on every side round its centre, and from its centre towards its extreme circumference. So that, throughout the whole of this spiral space, there is nothing but what is circular; there is no boundary, no end, no angle, but everywhere one and the same angle. By induction, therefore, upon the principles of philosophy and reason, it necessarily follows, that if the fluxion of the points be of the most perfect nature, their motion must be spiral; also, that if there be motion among the points, and if the finite, which has ends and limits, exist by motion, it cannot have its ends and limits by means of any

other motion than that which tends from the centre to a certain given circumference. Thus it has a limit in the centre and in every point of the circumference; a limit in every one point of the surface, extending to every other point in the surface; a distance between its points; space; a figure limited in the most perfect manner. In like manner, it may from principles of reason be *à priori* concluded, that the motion among the points is according to a spiral figure; because if the motion among the points finites any finite, and imparts to it limits, the same motion must be in every point, as also in every point the same power [*vis*] of moving itself; for, in the space comprehended by such a motion, there must be a motion in every point or *locus* of its space. A motion of this kind cannot be conceived except in a spiral, where the motion of all the points has the same tendency into the same circle; where likewise the motion can be continual; so that the motion of the points may be said to be most perfectly similar both among each other and within each other. Nor is anything more regular in its motion than the spiral; by no other motion could the points tend to their limits and finite anything, without confusion and disorder; by any other figure of motion the fluent points would become confounded before they arrived at their limit. Nor can any motion of greater potency be assigned than a motion flowing into a spiral. In no other figure is there latent a greater mechanical capability of penetrating from one extremity to another; of urging on anything to its destination; and thus of continuing a motion once begun, by the exertion of the smallest possible force and effort. This is evident from the nature and laws of the perpetual helix; which in every one of its points and at every angle, exercises the power of a lever; that is to say, is everywhere of the most perfect nature. In fine, if in a point and in the finites arising from it, we grant the existence of an internal motion, and of a state and conatus arising from that motion, then must this motion and state, according to all sense and reason, tend into a spiral. These observations, however, we adduce as being only *à priori*. They are arguments which it may be presumed will not sufficiently satisfy the minds of my readers; for we only conclude from certain reasons, that the motion must be spiral; namely, because it is of the most per-

fect kind and the most highly mechanical. Still the mind will not content itself with mere reasons; failing as they do to assign the geometrical cause, or to explain how it is that there may exist such a figure of motion between the points; how also it really exists; how, in the first spiral motion, there is geometrically such a force and quality, that the points cannot be quiescent among themselves, but must be in motion if they are in mutual contact; and how, when in motion, they cannot possibly flow into any other figure than such a spiral as we have described. Still as we designed to treat of the subject in its proper order, it was incumbent upon me to begin by explaining it upon philosophical principles and *à priori*. In the sequel we shall endeavour to meet the desires of the reader by explaining it geometrically.

20. *That if the continual motion be spiral it must be reciprocal; namely, from the centre to the circumference, and vice versa.* It is evident, I think, that if internal motion be granted, it must, for the alleged reasons, be spiral. But if the spiral motion be continual, it must be reciprocal. Without a reciprocation, it could not be continual. Nothing can spirate continually unless it spirate reciprocally. Without a reciprocal anhelation there is nothing continual; for there would be no fluxion from the centre to the circumference, if there were no reflux from the circumference to the centre; in fine, the very continuation of motion consists in reciprocation and alternation. If, therefore, there be reciprocation, and if the motion be spiral, we cannot conceive of such a motion taking place mechanically, unless a figure be conceived of such a kind as will admit of this flux and reflux of motion; nor even then could such a flux and reflux take place, unless in this figure *loci* were conceived on all sides, through which any point flowing to the surface might afterwards return. Unless in the figure such *loci* could be assigned, one point in its fluxion would encounter another; a single point would thus act as the cause of retardation and quiescence to another, whence all motion would cease. If, however, there be a regular reciprocation, then must there be on all sides in the figure of motion, *loci* through which the points may always return to the centre; thus there must also be a way from the centre to the circumference and from the circumference

to the centre, lest one point should encounter another. If, therefore, a reciprocal spiral motion be granted, it must be granted also, that, in the space thus comprehended, there must on all sides exist *loci* through which a reflux and reciprocation may take place.

21. *That from the motion of the points, parts, or individuals, arises the genuine and constant situation of all. Consequently, that in a finite, by reason of the spiral motion and situation of its parts, there arise two poles, one opposite to the other; and that these two poles are formed like cones.* Motion always precedes site or situation. Without motion there would be no disposition of parts. It is only by motion that parts are united into a disposition conformable to the motion and its figure. It is by motion that parts tend to an equilibrium. Motion therefore adapts the figure to the situation or disposition. Such as is the cause, such is the effect. It is thus that the parts remain permanent in the situation into which they ultimately come in consequence of their motion. Now since the disposition or situation of the parts is the figure of the motion, it follows, that in this situation all the parts continue to spirate, and exercise an effort to motion according to the internal force remaining in each individual. Already the parts are in such a situation, that they all spirate similarly toward the same motion, and act simultaneously as one common cause; so that there is no part which is not necessary, and which is not a part of the motion, and which does not contribute its own share to the general motion. One part consequently maintains a relation to the other; the adjacent, both to the adjacent and to the remote; the superficial, to the intermediate; the intermediate, to the central; the central, to the superficial; and so on through a regular circle. Hence every part is in series and connexion; the motion of one can be the motion of all as well as of itself; and this in a circle. Such a situation of the parts can be obtained only by means of the spiral. The communication and the reciprocation of motions, the circulation of whatever kind, when the parts are brought into a regular situation, are obtained by means of poles, whence there is a chain of connexion, contiguity, and motion, extending from one pole to another; so that the motion can, as it were, pass out of one pole and enter into the other,

and thus pass and repass by continuous circles and perpetual spires. The fact that, in such a motion or situation of the parts, the poles become, by reason of the mechanism of the motion and the geometry of the figures, formed like cones, will be explained in the sequel.

That, in like manner, in every finite ens, whose parts are disposed into a spiral figure, there are an equator, ecliptic, meridians, and other perpendicular circles. If there are poles, and if those poles be divaricated and enlarged into the figure of a cone, then there will be also polar circles, the dimension of which is the diameter of the cone. If there are cones and polar circles, there is an equator equidistant from the poles, together with meridians running perpendicularly through it from one pole to another. If the spiral figure prevail on the surface, as well as in the interior circles, then there are latitudinal circles formed by the spires in the surface; and if these are bisected at right angles, the ecliptic will pass through the sections. Thus do the poles form meridians and an equator; the spires form latitudinal circles and an ecliptic; thus also begins the same order in the microcosm which we see in the macrocosm, and thus the same, nearly at least, takes place in the smallest figure as in the largest, or in that of the world; for even in the larger, before the figures are developed, they are more inflected and incurvated. All these relations originate solely from the spiral motion. That it is in these things that consists the power [*vis*] and quality of producing a world, such as we contemplate and such as our senses perceive, or, in other words, of advancing the process of its formation to that end in which its phenomena can be placed before us geometrically, or in a manner conformable to its mechanism, will appear in the sequel.

22. *That from the regular disposition of the parts into a spiral figure, arises a general conatus of all, tending to one and the same general motion. That this conatus, if there be nothing extraneous to prevent it, causes a general axillary motion or circumvolution of the finite round its polar axis.* All conatus arises from motion. The parts continually spirate and exercise a conatus tending to the same situation, into which they are reduced by motion; because they spirate toward motion, so long as there remains in every individual part a power [*vis*] and cause of motion.

Motion, therefore, adapts the figure to the situation; and in that situation presents an image of itself. The figure of the situation composes the conatus, together with everything in the conatus similar to what is in the motion. In fine, the parts in their situation spirate and tend, by a conatus, into the same motion into which by their motion they had already arrived. There is an effort toward the same motion, so long as there remains in any individual any internal force. If the points or individuals are in respect to figure, motion, and force, perfectly similar to each other, they must come into a similar relative situation, and exercise a perfectly similar conatus. Among things absolutely similar there is only one mode, and it is from a mechanical necessity that they are confluent, by that mode, into their own situation and into no other. Hence arises the force and direction toward that motion, which is inherent in conatus. From the regularity of the parts exercising a similar conatus, the force receives determination and direction. When all the parts, therefore, unanimously conspire, and combine their efforts, toward any given motion, this spiration and effort is general or common to all; in other words, it is a spiration and effort toward a general motion of the whole corpuscle; a motion which cannot be any other than axillary. If we imagine a certain number of corpuscles mutually joined, and united to each other, every one of which, from its *vis insita*, is exercising a similar effort to motion; and if these corpuscles similarly cohere in a right line and in a series, then the effort or tendency of all is into a right line or into a series; and consequently the motion arising is in accordance with the effort or conatus. If the corpuscles were disposed and connected in their order, not into a right line but into a circle, so that every one of them exercised a conatus at the same angle in the direction of its tangent, then from this condition there would arise, were there no impediment, a general effort of all toward the figure of their situation, or the circle which their motion traces. The same result would take place, were small points disposed into a spiral figure; for since they have intrinsically the power of moving themselves, and since they all possess a perfectly similar force arising from their perfectly regular position, it follows, that no other effect can exist from this common cause,

than one common motion into which they all tend, and into which one impels the other, and consequently (by reason of the connexion and contiguity) the whole cohering series also; that is to say, they all tend to an axillary motion.

23. *That from the conatus to motion as exercised by all, there arises a progressive motion of all the parts and spires; but which is much slower than the common or axillary motion. That in this motion is preserved a similar situation of all the corpuscles, as likewise the same figure.* If all the points in a perfectly similar manner conspire into motion, and if the connexion and situation of the parts be such that they may be still further moved, that is to say, that there may be a figure of motion, then they cannot be quiescent; but, in consequence of the inherent force and effort remaining in every point, they mutually impel each other to motion. Let the situation of all the parts be assumed as a spiral, formed in motion and for motion; and thus presenting such an equilibration, that the motion of one part is the same with the motion of the other and of all the parts; so that the motion of the centre is that of the surface; the motion of the surface that of all the intermediate circles, and *vice versa*; it then follows, that all the parts in common are urged into motion. This motion, however, is slower than the common axillary motion, or that of the whole compound; because all the parts cannot move except simultaneously in their contiguity and connexion. When a point is moved at the surface, then, according to its situation and connexion, a point must become moved in the centre; and also intermediately between the surface and the centre. There is a consent of the parts to the same site or situation, because there is a connexion between them. In order, therefore, for the whole contexture to be in motion, the motion must be slower than the general motion round the axis. Indeed this motion can advance only a single step, while the common motion performs a whole circle. Nor indeed can the whole series and compages of the finite be put in motion, unless, in this motion, one and the same or a similar situation of the parts be preserved. For there is only one situation adapted to their figure and motion, in which they can be unanimously moved; and unless this be preserved, the equilibrium ceases, as also the mode, belonging to all, of moving

themselves conjointly and unanimously. In fine, the similarity and equality of the figure and conatus in all being given, there arises a mechanical necessity, not only of their being confluent into the same situation and composing a like ens; but also, by means of this situation, a necessity of preserving itself in every motion, fluxion and state, of retaining its equilibrium by the preservation of its situation, and everywhere perpetually observing the same mechanical laws. Thus it is, that the individual parts in their situation, which is most highly adapted to motion, necessarily move themselves, and in similar ways; so long as there remains in each such a force that one may become the effort, stimulus, and incitement of the other. It will be seen in the sequel, that this motion, which we have called progressive, follows the ecliptic; or that all the latitudinal circles or spires accompany each other; and proceed, at equal distances and in regular order, around their centre.

24. To avoid dwelling upon mere effects and causates, and too long deferring the consideration of causes, it will be necessary to premise *what is that thing in act, or that active force, in a point or finite, which, by a* vis insita, *produces this mutual motion.* This subject is of main importance. We have affirmed that, in internal motion, or intrinsically in a simple or individual part, there is inherent and permanent a power of putting itself in motion; and, by means of this, a power of finiting or limiting some new aggregate. Unless this power were in the individual parts respectively, they never could dispose themselves into a spiral, or into their figure of motion. Without such a power [*vis*] and quality, the points would, with all their general axillary and progressive motion, remain inert; one would not act upon the next adjacent, but would each be destitute of all determination and direction. As however we are now treating of points, these observations are introduced only by way of anticipation; for geometry is scarcely capable of entering into the analogy and ratio of a pure motion, or that which is in the simple. If there be a spiral figure, that figure must have a centre. The centre of a spiral cannot be in the same place with the centre of a circle; for a spiral is continually removing itself from the centre, and receding from the circle. The centre of the spiral must therefore be at a distance from the centre of

the circle. If the fluxion of the parts be spiral, then the centre of the parts spirally moved or arranged, is not in the centre which is in the middle of the corpuscle, but in one which is at some distance from it. Hence the centre of gravity is not in the middle, but is near the middle of the corpuscle, individual, or point. Let us, therefore, suppose the centre of gravity to be at a distance from the centre of the equator or outermost circle, and at the same time also from the axillary motion; it will follow, that, by the axillary motion, the centre of gravity also is rotated into the same motion, and the corpuscle becomes the most highly active at the point in which we find its centre of gravity, whence it becomes like an actual or active force [*tanquam actuale fit*]. The axillary motion being thus a motion in act [*actualis*] imparts to the centre of gravity the power [*vis*] and conatus of giving a direction to the whole corpuscle in accordance with itself and its figure; that is to say, into a second motion or into a figure of motion the same with its own. Conceive a corpuscle rotating round an axis, and the centre of this corpuscle gravitating not in the axis but near it; in this case, by means of the axillary motion, the centre gravitates in that direction in which it rotates with the axis; that is to say, it gravitates into a circle, together also with the axillary motion. But inasmuch as there is a progressive motion, in which the figure and situation of all the parts is preserved, it follows, that the centre of gravity also must continually observe the same motion and figure of motion. For if the figure and situation of the parts be preserved, and if nevertheless the motion of the parts be progressive, then, in this situation of the parts so preserved but at the same time in motion, the corpuscle progresses in like manner as the centre of gravity; and consequently directs its circular gyration into a conformity to its own situation and motion; that is to say, not only into a circle, but into a certain superficies; inasmuch as this centre moves only one step, while the axillary or common motion performs an entire circle. In fine, if the centre of gravity be not in the centre of the outermost circle, that is to say, in the centre of the corpuscle, but only at some distance from it; and if the corpuscle rotate round its axis; it follows, that the centre of gravity is perpetually impelling the corpuscle

to a motion extraneous to itself and circular. And further, if the motion of this centre be progressive, it follows that it endeavours to bring into the same figure of progressive motion (that is to say, a superficial figure) the whole of the corpuscle that is in motion. To place the subject in a clearer light; imagine the centre of gravity to be in the plane of the ecliptic; imagine an axillary motion in conformity with the equator: then, by reason of the centre of gravity, there will be a direction of the body into a circle or gyre conformable to the ecliptic. If the corpuscle have always an axillary motion, and if at the same time the centre of gravity move onwards but more slowly, then the second motion will be in the direction pursued by the centre of gravity or directing force of the corpuscle; hence the centre is not always being carried round in the same circle and gyre, but at every gyration advances another step, and this continually, at regular intervals; till, by progressive steps, it has completed the whole circle; which it does in order to form a concentrical superficies. The case is the same in our larger system. If the ecliptic continually cut the equator at equal degrees, and moments; and if the nodes thus continually progress until they have gone through the whole circle; it follows, that not one but perpetual and innumerable circles become described and represented; and, by means of these circles, as many superficies also. If the ecliptic be very distant from the equator, a larger and higher surface is represented; if the ecliptic be not very distant, a smaller and lower figure of surface is presented. These observations, however, are only cursory, and made with the view of shewing the reason for which the finite, the individual, or point, tends to a local motion, and consequently possesses an internal inherent power [*vis*] of moving and urging both itself and its proximate points; and thus by a continual and perfectly similar action, of disposing itself, together with these, into a situation the most conformable to its own motion and figure.

Therefore not only all the primitive force in the point, but that also which is derived into its sequents, consists in this; that the motion, state, or conatus in a point, tends to a spiral figure. This motion, state, and conatus, cause an axillary, and, at the same time, a progressive motion. These together produce another or

a local motion; a motion in which consists the active power [vis] *of finiting and compounding the sequents; and of modifying them throughout a lengthened series, in the manner in which we perceive, by our senses, the world at large to be modified.* We propose however to treat of each of these propositions more particularly.

25. *That the motion of all the points must be most perfectly similar and regular; that so also must be the progressive motion thence arising; and likewise, the second or local motion.* With regard to the figure both of this and of the progressive motion, it must be most perfectly regular. For the fluent points being perfectly similar, it follows, that the internal motion and state, in which alone they consist, must also be perfectly similar. Consequently, everything employed in producing the effect is most perfectly similar. A spiral situation of the points cannot subsist without the most perfect regularity; it is only by regularity and orderly sequence that the figure is maintained. If any inequality entered into this motion, it would immediately tend to stop it and disturb the connexion and series of the fluent points. The slightest inequality or irregularity in one would cause a similar inequality and irregularity in another; and so on successively in all, in consequence of the connexion between them; hence also in the whole finite. This motion therefore consists in regularity itself; so that one point always follows the same direction of motion as another; whence the motion of one is the motion of the other, and the motion of a volume or of all collectively is the same as the motion of one; or the motion of one, the same as that of a volume. If therefore, while in this regular situation, there arise a motion of the parts or of the whole, the line and figure of progression will also be most perfectly regular; and thus the moments and degrees be equal; whence a perfectly uniform figure will be produced. Parts which are perfectly similar and simple have only one way in which they can be moved; for all have a like potency, a like force and conatus, a like figure, and consequently, a like mechanism and geometry; hence, by a mechanical and geometrical necessity, nothing can exist but what has a perfect simplicity and oneness. In all there is only one and the same mode of moving themselves together with their

proximates; hence there can result only what has a oneness and similarity of modification. If the same and similar causes conspire to one end, then, the thing caused or the effect, is also similar; as much so as if it were the effect of only one cause; by a plurality, however, of similar causes, the force employed in producing the effect is rendered the stronger. Thus, from the similarity of all the causes employed, in producing the finite, there arises in the finite a perfectly similar situation, state, and conatus of all; there is a perfect similarity of figure, of consent to general motion; consequently, of general axillary motion, of progressive motion of the parts, and of their second or local motion.

26. *That these principles, however, cannot be proved by experiment, until we have arrived at elementaries.* The principles which are formed *à priori* by natural philosophy and a certain degree of geometrical connexion, receive likewise confirmation from visible nature; were this not the case, we should here be only building castles in the air. Still, however, at this stage of our subject, we cannot appeal to the testimony of experience; because we are as yet only at the first outset of our principles, where nothing can present itself to the senses in the way of phenomena. For as yet the entites are only such as begin to be compounded; they become elementary in the phenomena. Hence they cannot as yet constitute any element, and thus afford us ocular and perceptible experience; since this is first afforded only in the volume of elementary particles, and in an element reduced to some regular situation, in which the phenomena may first be mechanically represented. This however we are not to look for, until we come to treat of the second element; till then, we must travel in the road of philosophy and geometry. Our line of argument however will be legitimate, if, with geometry as our guide, we arrive at the station where elementary nature is rendered visible and sensible by experiments and phenomena; and if the connexion of our positions be so accordant with reason and geometry, that from the same experiments and phenomena their various intermediates receive confirmation; in which case, the intermediates leading to the element are themselves also experimentally verified. For if the ultimate end be expe-

rimentally attested and confirmed; and if the intermediates which lead thither from the first end be geometrically true, and depend connectedly one upon the other; then by the same experience the intermediates also are attested and confirmed. In like manner, if any intermediate be experimentally and geometrically true, the whole chain of connexion extending from the first end becomes verified experimentally and conformably both to geometry and nature. In the present case, however, we have as yet no phenomenon derived from these finites, and presenting itself immediately to the senses, unless such an one as is drawn from a very remote source, as for instance the following. We see that the motion of the free and elementary parts tends to a certain spiral gyration; that all mechanical power is inherent in this motion, and owing to it. We see the solar vortex itself tending to flow into a similar gyre, and forming by a fluxion of this kind larger and smaller circles, also ecliptics, equators, meridians, and all the other circles belonging to the earth and the heavens; imitating on a large scale the modes of the smaller and simple; or else, the simpler and smaller imitating the motion of the compounded and larger. That there is a certain situation of parts according with these circles, is manifest in the universe at large and from innumerable evidences presented by the different bodies which flow among these particles or in any volume of these particles. In a word, the whole visible world appears to be full of proofs, that the general situation of its parts is in accordance with certain circles of the world; the consequence of which is, that the parts which cause this general situation are similar themselves. Of this subject, however, we shall treat in our observations on the First and Second Element.

27. The kind of connexion which this finite maintains with the point is evident from this; that the finite derives its origin from the point, and that it flows from the motion of the points one among the other; that the motion in these finites is similar to the motion in the point; that in this finite there is the same power [*vis*] of producing sequents as there is in the point of producing this finite; that there is thus a connexion between them, arising from the circumstance of one existing from the other, or the finite existing from the point; thus that there is a

connexion of causes in producing the compound. *Without a connexion, similarity, and derivation of causes from one into the other, not a single natural thing is produced* capable of maintaining, through intermediates, a continual relation to its first origin. Unless there were a connexion between the existence of one cause, and that of another leading from one substantial to another, there could be no end, nor any mean leading to that end. The end would be where the connexion ceased; and as to an intermediate, there would be none. In the view we have taken of the subject, we see not only the origin of the finite from points, but also its connexion with them both in regard to existence and causes; we see the finite derive its origin from a cause latent in the point; and that, by means of a similarity of motion, the same cause is translated, as it were, into a finite of such a kind as in like manner is able to produce its own similitude. Here then is the connexion between the point and this finite.

CHAPTER IV.

A PHILOSOPHICAL ENQUIRY CONCERNING THE SECOND FINITE, AND THE MANNER IN WHICH IT DERIVES ITS ORIGIN SUCCESSIVELY FROM THE SIMPLE FINITE. ALSO, GENERAL OBSERVATIONS ON ITS COEXISTENT; WHICH WE HAVE DENOMINATED THE ACTIVE OF THE FIRST FINITE; AND ON THE MANNER IN WHICH IT IS GEOMETRICALLY DERIVED FROM THE FIRST AND SIMPLE FINITE.

Our world as yet is lying only *in ovo*. Nothing which can be called elementary has hitherto received birth; no active as yet exists, which, when joined with any finite or passive, produces the essence of any element. The world, which as yet lies *in ovo*, consists solely of the least possible finites. No point now appears existing by itself, for every one is in this minimal finite, into the substance of which it has entered; so that as far as regards existence by itself, the point has entirely vanished.

2. *Since therefore the finite is universally only of one kind; and since each one is most perfectly similar to the other*, as being the first finite or smallest substantial; it follows, that, as yet *this is the only thing which can procreate anything from itself.* Until now we find nothing in the whole nature of things capable of modification, besides this first substantial and afterwards the finites or entities proceeding from it. Imagine, therefore, a universe of this kind filled with these minimal finites; and in every one of them a force and quality similar to those in the point, and derived into the finite from the point; it follows, that, by the same law of connexion, a certain similar finite derives its existence from the fore-mentioned minimal finites,

but one comprehended within more numerous and larger terminations and limits: there arises, in fact, what may be denominated another finite. This other finite cannot arise from itself; it must arise only from one more simple than itself. But besides this finite, nothing is extant but the first and least substantial; from which, as being more simple and the only thing existing by itself, this second finite derives its origin.

3. *Nor can it derive its origin from the more simple and only existing finite except by means of motion,* which is the only thing that binds together the particles, which reduces them within their given limits, and which keeps them there. Without motion, as we have frequently observed, nothing can be finited and limited. It is motion which gives both figure and space; which distinguishes one aggregate of minimal finites from another; which fixes a measure between the centre and the ultimate end, or between one end and another. It is motion, therefore, which is the mean and cause of the first finite existing in the second and more compounded.

4. *Nor can any motion be conceived between the finite substantials, unless also its cause be at the same time conceived.* Now the cause cannot be conceived to exist out of the substantials, since these are the only things which as yet exist. *The cause therefore, must be in the substantial itself,* and inhere in it as a something essential which produces the thing caused. If, therefore, in the first substantial we have a situation of parts or points forming a continuous spiral series, and if there be a conatus to an axillary and local motion, we are immediately supplied with a cause and power [*vis*] by means of which these first substantials are enabled by their motion to become confluent into some new finite.

5. *But the cause cannot be efficient, or give rise to a causate, unless there be some contingent* by means of which it may effect its procession [*prodire*]. The contingent is this: that *the series and abundance of these smallest substantials is so great, that one is in contact with the other,* and that all in consequence are in a state of mutual pressure. Unless this contingent were afforded, the new finite could not be conceived to become extant. If there were no such contingent as this, that so great was the abundance of substantials that one pressed upon another, or

that they became a volume or large aggregate, then there could not by the operation of this cause, exist any finite similar to its prior or parent; but, in the place of this finite, there would be an active, of which we shall speak in the following chapter.

If, therefore, there be a least substantial, and if in this substantial there be latent a cause of producing a new finite, then *we can conceive the existence of only two contingents; one being this, that so great is the abundance of smallest substantials, that one by contact presses upon the other; a contingent from which exists a new finite: the other, that the abundance of smallest substantials is not so great that one by contact presses upon another; a contingent from which exists the active of the first finite.* Let us however come to the definition of our finite.

6. *It is another finited ens existing from the motion of simple finites among themselves. It is therefore another substantial arising from all the finites.* That it is another substantial arising from the motion of the finites, is evident from this; that the universe consists as yet only of first and least substantials, and consequently cannot derive its origin from any other source. Likewise, since there is a connexion of all the finites with the first ens, this second finite existed successively from that which proceeded from the first simple ens, that is to say, from the first substantial.

That this finite came into being mediately by motion, is evident from this; that there is nothing but motion which can give existence, and which can finite boundaries or fix them to certain limits. It is motion only which can give figure and space: without motion nothing could be confluent into a limited aggregate: the cause for which anything can be finited consists solely in motion. *It is motion, therefore, which distinguishes, finites, configurates, makes one thing equal to another, retains it within its limits, and so holds it together as to be enabled to subsist as one finite ens capable of being separated from another.*

7. From the foregoing remarks it follows, that *this finite consists only of simple finites:* because it is from these alone that it derives its origin.

8. *That it is not divisible into anything smaller than the simple finites of which it consists.* By division we here understand such as is geometrical. Hence, in this division, we cannot

procced farther than the first substantials, from which it exists. Geometrically, it is not divisible into points; because points are mere simples, and consequently beyond the sphere of geometry.

9. *That it is another geometrical ens which is limited, but in very small boundaries; and that there is no finite which is smaller, except the first substantial of which it consists.* This follows from the theory of its origin and existence.

10. *That it is endowed with a figure similar to that of the first substantial.* For it arises from the first substantial, just as the latter arises from the point. It derives its origin by a similar mode and motion, and consequently by a similar figure of motion. Since then its origin is similar, as also the motion by which it arises, it follows that the figure thence arising is similar. From similarity in origin, figure, motion, and cause, nothing but what is similar exists; the difference being only that of dimension.

11. *That its figure approaches as nearly as possible to the most perfect figure of the finites; but, notwithstanding, that it is itself not the most perfect. That the figures of all these finites are similar; but that, nevertheless, a certain dissimilitude between them may be assigned.* We have said that the figure of the simple or point is the most perfect, and consequently the most perfectly similar; the next to which, in perfection, was the figure of the finite; because it had proceeded from a simple and most perfect ens. With this first substantial, however, first begins mode. This it is which first begins to be susceptible of modification; for modification appertains to that which is substantial;* and everything substantial is susceptible of modification. Everything which is dissimilar, and recedes from perfection, arises from modes. The more numerous therefore are the modes, and the longer the series of their succession, the greater is the dissimilitude, and the more imperfectly does the thing exist. If the series of modifications be manifold, so great may become the dissimilitude between entities compounded by the modifications of antecedents, that not one shall appear similar to another; not one shall be perfect either as to figure or any other essential. By modes therefore it is, that exists whatsoever

* Substance being, by its very definition, the subject of modes, or a subject susceptible of modification. See Wolfe's Ontology, art. 768.—*Translator.*

renders anything imperfect and dissimilar. Now since the first substantial is the first ens susceptible of modification, nothing can be conceived in it as geometrically imperfect and dissimilar. In, however, its subsequent or second finite, something dissimilar and imperfect begins to be capable of existing; because this finite arises by the modification of the prior, and from the prior. Still the dissimilitude and imperfection in this finite cannot be so great as in the entities which succeed. No entities, therefore, which are frequently compounded, can be palpably and absolutely similar to each other.

12. *That the internal motion, situation, and state of this finite are similar to the internal motion, situation, and state of the first substantial;* for from a like cause, power of motion, quality, and figure, by which the substantial originated from points, does this finite also originate from the first substantials. Consequently the effect, causate, and impression [*causatum & signatum*] must be similar; a conclusion which is geometrically evident.

13. *That the motion of the whole, or the common axillary motion, the motion of the parts or the progressive motion, as also the second motion, if it has room to display itself, is similar to the common, progressive, and second motion of the first finite.* From a like cause proceeds a like effect. In the individual parts of this finite, or in the first finites, exists nothing dissimilar, unequal, or angular; the figure of all is similar, as likewise the figure of the situation of the points. In all there is a like space, a like motion thence resulting, whether axillary, progressive, or local; as also a like force and conatus tending to these motions. Both kinds of entities or finites, therefore, are geometrically and mechanically similar. There is nothing angular either in their figure or in their motion: whatever is within them is circular, because it is spiral: whenever any inequality arises, it arises in consequence of inequality of figure, or difference of angles. Hence it may be geometrically concluded, that nothing dissimilar can be produced from what is purely circular and spiral. In the very production itself there is a mechanical necessity, that what is produced shall be similar to that which produces it. There is derived therefore into this finite, from the primitive force, a similarity to itself, both in

regard to figure and motion, whether axillary, progressive, or local. *From the same causes, also, it follows, that the situation and progression of the centre of gravity in the second finite, is similar to the situation and progression of the centre of gravity in the first.*

14. *That the celerity of the second finite, in regard to its general, progressive, and local motion, is less than the celerity of the first finite.* The modification of active force consists in celerity. It is by celerity that the state of the active force is determined; so that celerity is thus as it were the limit of the motive force. In order to move a larger mass from its place, a greater active force is required than in moving a smaller. There must always be a ratio between the active force and the mass. If there be the same active force and a larger mass, the celerity becomes less than it would be if the mass were smaller. In the present case, the active force remains the same: both because the figure is similar and one and the same, and because the number of parts is both similar and the same. The mass, however increases according to the degree of composition; consequently the ratio between the active force and mass becomes greater and more dissimilar; consequently, also, the modification of the active force, which consists in celerity, becomes less; that is to say, there is a less celerity in the mass and larger compound than in the smaller; for which reason the celerity of this finite, both as to axillary, progressive, and local motion, becomes less than the celerity in the first finite.

15. *That the first ratio of celerity is in the motion of the first finite; that the second ratio is in the motion of this second finite; and that this finite is, in regard to substance, the second boundary.* In the first finite there is a ratio between its progressive and axillary motion; the progressive is slower than the axillary; and hence we are supplied with the first ratio of celerity. In the second finite, also, there is a ratio between the progressive and axillary motion; hence we are supplied with a second ratio of celerity; and since the first ratio is similar to the second, we hence establish this analogy; that as the progressive motion of the first finite is to that of the second, so is the axillary motion of the first to that of the second. In regard to substance, however, this second finite is a second boundary;

because, in the first substantial is the first boundary, and in the pure simple there is none.

16. *That in itself, and in its own internal state and motion, it possesses the same force and quality as the first substantial; so that it is able to finite and produce succeeding and more compounded finites; that is to say, it has received from the first substantial all its power* [vis] *of finiting the sequent. Nevertheless, that this power is no longer that of the first substantial, so as by it to be able to finite; but that it becomes its own proper acquired power.* That in this second finite there is the same quality of finiting and compounding sequents as there was in the first, follows from the similarity of internal motion, progressive motion and figure. Similar motions in each supply us with a similar causate. This power or force, however, no longer pertains to the first substantial; because this had previously exhausted its power in compounding this finite, and so preserving its state, as for it to resemble itself. Hence its force is now derived into its progeny, which, by reason of its similitude, possesses in potency the same which the first substantial had in compounding it.

17. *That in relation to things much finited and compounded, it is small, and as yet scarcely comprehensible geometrically.* Since it is next to the least substantial, it must necessarily be small; and particularly in relation to things much finited. That it is as yet scarcely comprehensible geometrically, appears from this; that, in regard to substance, it is only the second boundary. Geometry requires at least three boundaries before it can determine anything by analysis. There must, therefore, be a third before geometry can acknowledge this finite to be a legitimate subject for its consideration.

18. *It cannot be concluded from principles of geometry, but only from those of reason, that the motion in a point is spiral. However, in the motion and situations of the sequents, both the geometer and natural philosopher may see that it is spiral.* Geometry only defines figure, describes it by lines, investigates its angles and other properties, and gives demonstrations pertaining to these by an analysis and rules proper to itself; but it is unable to demonstrate that there must be a figure of this nature in the point and first substantial. That both in the

point and in the first substantial, there is such a figure must be concluded from arguments *à priori* and *à posteriori*; next must come mechanics with its powers; and finally geometry. If therefore it be taken for granted, that this figure of motion exists in the first substantial, then a similar figure of motion in its subsequent products follows by a geometrical and mechanical necessity.

That reason may infer *à priori*, that there is such a figure in the point, the first substantial and the succeeding finites of the same quality, appears from this; that reason is unable to admit any other cause or any other medium of existence or of being, but motion; since without motion, and without change of state by means of motion, nothing further could possibly exist; it therefore acknowledges motion as the first thing which produces anything. The same reason, likewise, acknowledges, that by such a motion there is an occupation of space; that this space has its limits extending from one extremity to the other, from one point of a limit to another; that the space, therefore, has figure; because reason cannot designate motion without space, nor space without figure, which are attributes of motion. Nor can reason admit of the existence of motion, unless at the same time it admits of a given direction, or some course along which it tends; that is to say, some figure of motion before the space is formed, or some track which the motion, as it proceeds, describes and figures out. Nor does reason stop here, but advances still further; inferring, for instance, that among the finites there must be some first thing which is least, and that there must be some simple antecedent to the least finite. Here reason stops, because into the infinite it cannot penetrate. It therefore acknowledges, that the first origin of things is in the simple; that in the simple there is a certain motion, together with all the attributes of that motion; just as in things not simple, but only so analogically. Admitting therefore, as it does, the existence of motion in the simple, and the origin of things to be from the simple, it must also admit in the simple the existence of something most perfect, equal, and similar; for it as yet discerns no mode, except the one which has to arise from the first and least substantial, and its successives; it consequently sees nothing that is mutable, unequal, and dissimilar,

except in those things with which modes exist. Without modifications it can know of no change of state, or variation, in the limits of any ens. Whatever, therefore, it admits as being in the simple, it admits as being most perfect; and if it be most perfect, so also must be the figure formed by its motion. Reason, therefore, perceives that there must be something in the motion and figure of the simple, which is most perfect; if there be something most perfect, then, from a series of conclusions drawn from *à priori* principles, it will admit that so also is its figure the most perfect; and the only figure which has this degree of perfection is the circular; and if the figure of motion be conceived as being in space, then no other can be conceived than the most perfectly spiral. Nor does the chain of reasoning stop here, but proceeds still further; so that, by adding one link to another, we can make it reach to geometry. Thus if the figure of motion be spiral, and if the motion which runs out into this figure enclose space, reason immediately concludes, that the figure of the motion is such that its ultimate termination is a circle; because a circle is the ultimate circumference to which the motion by a spiral course arrives, and because it cannot, by any spiral course, go beyond this circumference; and if so, then all its spiral motions must end in the circular, or that which terminates its surface or is the ultimate of its motion, and in which are the limits both of its motion and of its figure. Granting this, that is to say, granting the existence of a centre, a circumference, and a spiral figure of motion from the centre to the circumference, we are enabled to infer the quality of the figure of spiral motion. For reason perceives from *à priori* principles, that the spirals which are nearest the centre must be the most highly spiral, and that those nearest the circumference must be the least spiral; that is, they are almost circular. The same is the case with the figures of motion between the centre and circumference. The spirals near the centre are the most highly spiral, and the more the motion approaches to the ultimate circumference, the less spiral do they become; till in the last circumference itself, they become the least spiral. Thus we may arrive *à priori* at the figure of motion. Geometry, which does not venture beyond its lines and analyses, is itself unable to conclude that the figure must be of the kind we have men-

tioned; but only shews by its lines and calculus what the boundaries of such a figure are.

Reason, whether *à priori* or *à posteriori*, or both together, is enabled to see that one finite proceeds successively from another; and that in order for any new finite to be created, there must be a motion of the finites one among the other; it concludes, that in the preceding finite there is a certain force, in virtue of which it may be put in motion, in order for the succeeding finite to exist; that in motion is the cause and the very force itself, or that which causes the existence of the sequents by a motion one among the other. *Reason concludes therefore* à priori, à posteriori, *and from both together, that the figure of the motion must be such as possesses within it such a force and quality as to enable it to be the cause of the sequent,* or the cause of some motion by which the sequent may be procreated. Such then is the extent to which we may proceed by argument *à priori*, or by rational and natural philosophy.

Here, for the first time, we begin to receive assistance from mechanics and its powers. Without the help of mechanics we cannot conclude anything with certainty. We must confirm our *à priori* observations by mechanics, and consequently by principles drawn *à posteriori*. The science of mechanics then confirms the fact, that it is in the spiral motion that resides all its power of freely flowing from one extremity to another, and that it cannot arrive at any end by any other motion more easily; so that, if anything is to be conceived as continuously in motion, that continuity must be conceived of as spiral. *In the lever, mechanics sees its potency and forces; in the inclined plane, its motion; in the perpetual lever, a perpetual potency; in the perpetually-inclined plane, perpetual motion; in the spiral figure, which represents both, it sees concentrated all its capabilities.* From mechanics we learn, that a body in motion moves according to the centre of its motion, or the centre of gravity; and tends in the direction in which its centre tends; all the parts of the body conspiring with the centre. *If the centre of gravity consist in motion, so that the centre is itself formed by a continuous and perfectly regular motion; in this case, we learn from mechanics, that such a body, already in motion, has a tendency to a still further motion, which is under the direc-*

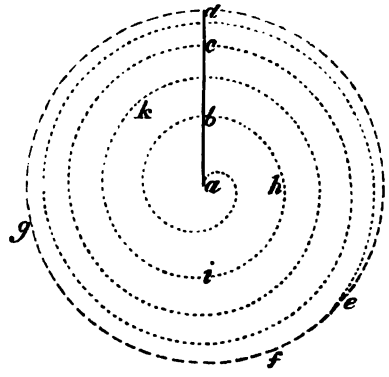
tion of the centre of gravity. Reason itself sees that there is nothing else to direct such a body but its centre; with which all the parts of its internal state conspire; or in which all the parts as it were, moments or degrees of motion are concentrated. This central point will be the directing point of the whole body, because no other point in the body can direct it; the direction must therefore be according to the centre of the body. *If therefore this centre of gravity be not the centre of a quiescent body, but the centre of some motion, it immediately becomes lively and active, or a living force, which in a quiescent body is dead and inert.* Mechanics, likewise confirms the fact, that a body put in motion moves according to its centre; and that a body, consisting entirely of motion, not only moves according to its centre, but that by this motion its force becomes living and actual; that is to say, it has a tendency to move with the whole of its body consisting of motion. But of this we shall speak in the subsequent chapter.

We must now finally come to the principles of geometry with its lines and calculus. For geometry shews not only that such lines as we have mentioned, may be assigned; but that, when assigned, the diameters, angles and circles they form, have their ratio and analysis.

19. *We proceed then to the geometry of this spiral.* The reader must pardon me, if I here detain his attention by lines and geometry, while perhaps he may be wishing to hasten on to the important subjects which await us in the sequel.

In figure 1* we have the spiral figure formed by motion, where the motion begins in the centre *a*, and by continued spires passes through *b*, *h*, *i*, *k*, to *d*, *e*, *f*, *g*, or the ultimate circumference, which is circular, and in which the motion terminates; so that the entire limit of the spiral is equi-distant from its centre.

Fig. 1.



* In the original, plate I. fig. 5.

Now since this figure is described by motion, this motion must be either greatest in the centre and least in the circumference, or least in the centre and greatest in the circumference. There is no third alternative, unless it be a state of quiescence. By either of these motions is formed a spiral, whose boundary is a circular circumference. Let us first enquire, on geometrical principles, into the spiral figure which is formed, when the motion is greatest in the centre and least in the circumference; and from this derive our inference with respect to the other. That the geometry of this spiral may be better understood, let us conceive of it as some large or immense volume, forming by its spiral motion a vortex; for geometrical figures are more easily apprehended when represented by large, than by small, boundaries.

If the motion be greatest in the centre, and least in the circumference, then it must gradually diminish as it passes from the centre to the circumference. The diminution of this motion must be in a simple ratio; because it arises only from the resistance of the fluent points; and since there is a consecutive series of these points from the centre to the circumference, the motion is retarded by this series at every successive step; and inasmuch as the cause of retardation and resistance is simple, the ratio of celerity is simple; so that the greatest celerity is in the centre, a less in the circumferences, and the least in the ultimate periphery. Hence at each step of the progression, the celerity in the several circumferences becomes less and less:* it is less in *b* than in *a* (fig. 1.); less in *h* than in *b*; less in *i* than in *h*; least in *de*; and none in *f*, *g*. This ratio is only the simple one of the distances from one point of the arc to another, and so on. Since every successive resistance arises from the series of points flowing into the same figure, and the resistance can be contemplated only according to the figure into which the series of points flows; it follows, that according to the figure itself, the ratio of celerity is simple; but not so, if considered in reference to the diameter from *a* through *b*, *c*, to *d*.

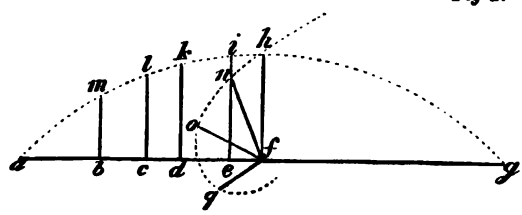
Since the motion is spiral, and is every moment more and

* Several errors of the press, in the original, are here corrected; as also more particularly in the lettering of figure 3, and in the demonstration.

more directly receding from its centre by the radius or diameter; another ratio presents itself, which must be taken into consideration, both as it is in the spiral series and at every successive distance from the centre. Since we have thus an additional ratio, we have in this case, according to the common rule, a duplicate ratio from the centre to the circumference, or a ratio in accordance with the diameter from *abc* to *d*. Thus, when a body falls through any medium, if at each moment there be added to its natural simple arithmetical ratio of celerity, a certain further degree, the celerity becomes duplicate; or it is the ratio of the simple ratios to their squares.

We may institute in this manner a comparison between the spiral and the parabola, whose ordinates and diameters are in a duplicate ratio, or in the ratio of a given number or line multiplied into itself, or of its square to its cube. When the ratio, therefore, is given, spirals may be transposed into another curve. Thus—

Fig 2.*



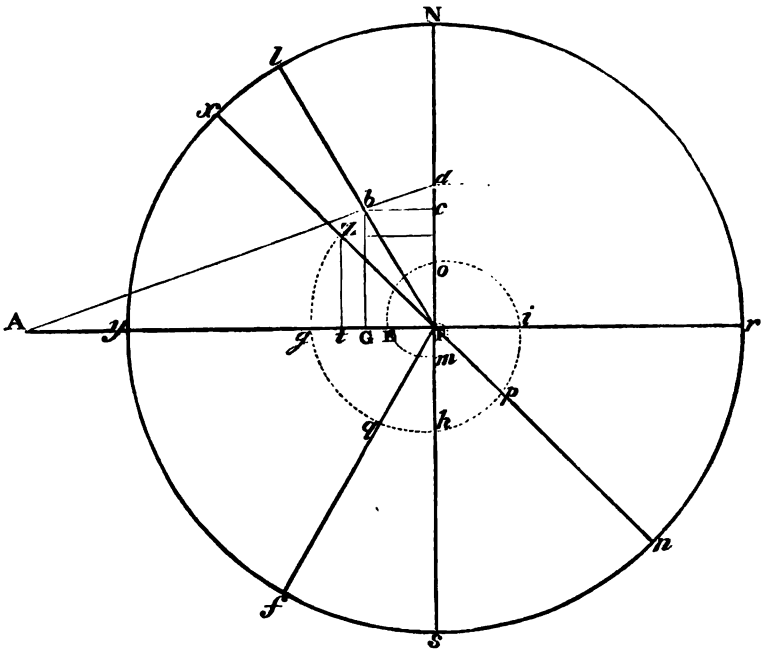
the spiral diameter *fq* may be transposed to *b*, as *bm*; *fo* to *c*, as *cl*; *fn* to *d*, as *dk*. Or we may take any arc of a spiral (for the most simple ratio is in the arc), and regarding it as an axis, may erect upon it all the ordinates of the spiral.

The ratio of the spiral figure being given, its lines may then be ascertained by an analytical computation of differences or minimals (see fig. 3). Since the figure is spiral, it follows that all the circles continually recede from their ultimate circumference, and approach nearer and nearer to the centre; and that no two points can be given which are equi-distant from this centre; no two diameters equal to each other; for N*d* is more distant from the centre than *yg*; *yg* than *sh*; *sh* than

* In the original, plate I., fig. 7.

ri; *ri* than N*o*, and so on. Now the ratio of these being duplicate, their differences are in arithmetical progression, as 3, 5,

Fig. 3.*



7, 9, 11. The differences of these, however, or the differences of the differences, are always equal; just as in the foregoing numbers, 5−3, 7−5, 9−7, 11−9=2. Let the altitude as given by the diameter from the circumference of the spiral to the centre,=*l*; the difference=*a*; the difference of the differences=*b*; then if *a*=3, *b* will=2; and *a*+*b*=5; *a*+2*b*=7; *a*+3*b*=9; *a*+4*b*=11, and so on. Let now the altitude N*d*=*l*+1, and it follows, that *yg* may=*l*+*a*; *sh*=*l*+*a*+*b*; *ri*=*l*+*a*+2*b*; N*o*=*l*+*a*+3*b*; *y*E=*l*+*a*+4*b*; *sm*=*l*+*a*+5*b*, &c. The intermediate parts are obtained from the ratio of the angles; for if N*d* be to N*o* in a duplicate ratio, then we have the difference *do*; and because the differences of the differences are equal, they will be in the ratio of the angles; hence when N*d* is given, so is *sh*; so also in the same

* In the original, plate VI., fig. 4.

circle is given N$d-sh$; as also the halves of do; and consequently xZ, which is midway between d and g, will $=l+1+\frac{1}{2}b$: and fq which is $\frac{2}{3}$ of the distance from g to h, or $\frac{2}{3}$ of the quadrant, will $=l+a+\frac{2}{3}b$; and pn, which is midway between i and h, will $=l+a+1\frac{1}{2}b$. Now let the angle bFd be assumed as $=\frac{1}{12}$ of a circle, or 30 degrees; or let it be $\frac{1}{3}$ of the quadrant of a circle; then $lb=l+1+\frac{1}{3}b$; in short, by the differences of the differences we obtain dF, bF, ZF, and all the diameters in the same quadrant. We obtain, therefore, by these means bF, the angle bFd, and the right angle at c; we also obtain bc and GF; likewise cF or bG; consequently the proportion bG : dF :: yG : yF, or the equation of the spiral curve in its quadrant. The same method we pursue in obtaining other values. When, therefore, in any quadrant, the equation of the spiral circle is given, we may then, in the usual way, form the differential triangle dcb,* and consequently by proper formulæ and the differential calculus, we may obtain the subtangent FA, the tangent dA, the rectified curvature dg, the area dFgZd, and any other value we please.

That the reader may better understand the subject, we will add another explanation.

If the ratio of the diameters be duplicate, the differences of all the diameters are in a certain arithmetical proportion, and the differences of these differences are always equal. If in our computation, the semidiameter Fd be assumed $=d-a-b$, and F$o=d-a-mb$, then all the semidiameters from d to $bZgqhpio$, as far as the centre, differ in arithmetical proportion and according to the ratio of the angles. If F$d=d-a-b$, and F$o=d-a-mb$, and the angle subtended by $db=\frac{1}{24}$ of a circle, then the semidiameter F$b=d-a-\frac{mb}{24}$. The radius Fg, where the quadrant is, $=d-a-\frac{m}{4}b$, F$h=d-a-\frac{m}{2}b$, because it is the half of the circle, and so on to F$o=d-a-mb$. In this manner we may obtain any semidiameter; as we here do Fd and Fb at a given angle; and the angle bFd, the right angle at c, and the semidiameter Fb being given, we obtain bc and GF, consequently the ratio of the ordinates bG, Zt, &c.; also the ratio of

* The reader will perceive that the same figure is used to answer different conditions.—*Translator.*

the abscisses gG, or gt, or gF, or the equation of the spiral curve in any quadrant. This being found, we obtain the differential triangle *bcd*; and consequently, by further calculation and formulæ, the tangent dA, the subtangent AF, the curvature dZg, the area dbZgF, as also the centre of motion or gravity. If m, or the difference of the differences $=4$ or $\frac{3}{9}\frac{6}{0}\frac{0}{0}$, that is to say, if $d-a-4b=d-a-\frac{3}{9}\frac{6}{0}\frac{0}{0}b$; and if any angle be given (as one of 30°); then for 360° substitute this angle, so that instead of $d-a-\frac{3}{9}\frac{6}{0}\frac{0}{0}b$, we shall have $d-a-\frac{3}{9}\frac{0}{0}b$. If the angle be 75°, then it will be $d-a-\frac{7}{9}\frac{5}{0}b$, and so on.

We now come to the laws of motion. Let such a vortex as we have spoken of be conceived upon a large scale; or let us imagine a spiral motion running over a considerable extent from the circumference to the centre, or, as in the present instance, from the centre to the circumference. Let this motion be least in the circumference and greatest at the centre. In this vortex, let a certain very heavy body be conceived as falling; in which case we affirm, that a body, heavier than the vortical element or its volume, will be carried from the centre to the circumference; but, if lighter, it will be carried from the circumference to the centre. For the heavier body follows the stream of motion, and tends with this motion to circumferences more and more remote, till it reaches the last. If the gravity of the body be such that it cannot be whirled by the stream of particles into a vortex, then it will tend from the centre, along the diameter, to the circumference. The contrary will be the case, if the falling body be lighter than the volume of moving particles in the vortex.

With regard to the velocity of the very heavy body in falling from the centre to the circumference, this velocity will diminish in a duplicate ratio to the distances from the centre. For the motion of the body falling (represented by the diameter of the vortex) from the centre to the circumference, will be similar to the motion of the parts in the vortex; which, in the direction of the diameter from the circumference to the centre, is in a duplicate ratio. If, however, the motion be greatest in the circumference and least in the centre, then the velocity will increase; and for the same reason as before, in a duplicate ratio to the distance from the centre to the circumference.

If in the vortex in which the motion is greatest in the

centre and least in the circumference a heavy body tend from the centre to the circumference, and in its course does not move along the diameter, but is deflected by the vortex into innumerable spiral circles before it arrives at its ultimate circumference; then we affirm, that the velocity of this body is diminished almost in a simple ratio; but, in a diameter or line described by a perpendicular fall, its velocity is diminished in a duplicate ratio. For if the body be carried sideways into circles, it is carried into almost the same stream and motion as the fluent parts; which move in a simple ratio through the curve of the spiral, but in a duplicate ratio through the diameter. If, however, the motion be least in the centre and greatest in the circumference; and the body, as before, be carried sideways into gyrations; then its velocity is almost in a simple ratio from the centre to the circumferences, that is to say, in its passage through the spiral circles, but not so in a perpendicular course along the diameter.

If any body moves not in a right line along the diameter to the circumference, but through circles, it follows that its gravity is not so great but that it may be carried along in the vortical current. If any heavy body descend from the centre of a vortex of this kind to a certain given circumference within the vortex and there stop; it follows, that in this circumference there is an equilibrium of its weight, and of the volume of those parts of the vortex which are in this circumference, or at this distance from the centre.

If a body stop in any given circumference, or at any given distance from the centre, it follows, that it is carried into a circle, and revolves around its centre always at an equal distance from it. For since it stops at a certain distance, it is in a state of equilibrium with the volume of the parts at this distance; consequently it is carried by their motion into a circle; but in whatever part of the circle it is, there is the same equilibrium. Hence, in consequence of its preserving an equal distance from the centre, it moves in a circle.

If the body revolve around a centre at an equal distance from it, and hence in a circle, it follows that the motion of this body in the circle is always uniform. For, at the same distance from the centre, the velocity is the same; this velocity being,

as we have said, increased or diminished in a duplicate ratio to the distances from the centre.

If in any volume of the parts of a vortex, at the same distance from the centre, a body be so directed as to move to ulterior circumferences, it follows that, in pursuing this direction, the body moves along some other course than the common one of the vortex; and a curve is described, partaking both of a duplicate and of a simple ratio. The motion in this curve is not unlike the motion of a projectile in the vortex, and partakes of a velocity both equable, and accelerated in a duplicate ratio.

If a body in this vortex, tending from its centre to some circumference, become, from certain unknown causes, lighter and lighter, it follows that its motion is nevertheless in such a ratio that its differences are in arithmetical progression; and that the differences of these are equal: as in the case of a body falling along the diameter from the centre to any circumference. For if at each moment the body did not become lighter and lighter, the velocity of the body running outwards would be in a duplicate ratio. But if at every moment there were an accession or recession of anything which increased or diminished the velocity of this motion, observing a duplicate ratio, still the differences of its differences would be equal. This, however, would be the case, only if the body issued out along the diameter in a right line from the centre.

With regard to the velocity of a body, at any distance from the centre of a vortex in which the motion is greatest in the centre and least in the circumferences, I observe, that it is in a duplicate ratio to the distance in the diameter from the ultimate circumference. Let the distance from the highest circumference to the centre, or the diametrical length $=l$; the velocity $=c$. Then according to the common rule, $l : \mathrm{L} :: c^2 : \mathrm{C}^2$; that is to say, the velocities are in the subduplicate ratio of the lengths or distances from the ultimate circumference. Or thus, if the whole distance from the ultimate periphery to the centre $=z$; and $z-l=r$ one radius, and $\mathrm{Z}-\mathrm{L}=\mathrm{R}$ the other radius; we shall then have this analogy; $z-r : z-\mathrm{R} :: c^2 : \mathrm{C}^2$; or the velocities are in the subduplicate ratio of the differences of the radii. If the motion be least in the centre and greatest in the circumference, then the velocity is in the duplicate ratio of the radii.

In the same manner the times are in the subduplicate ratio of the distances from the ultimate circumference to the centre; for, according to the general rule, the times are as the velocities. Again, in the contrary case, or that in which the motion is least in the centre and greatest in the circumference, the times are in like manner in the subduplicate ratio of the radii.

If the medium through which the body falls, or the volume of particles, be different in two different vortices, the same body will require a longer time for its fall in one medium than in the other; although it will continue to observe a duplicate ratio to the distance in its perpendicular descent; and also in each medium a like ratio of velocities and times, with a difference only in degrees and momenta. Hence if, with any velocity which the body ultimately acquired in its fall from the ultimate circumference to some other which is nearer the centre, it moves equably through a circle or in a right line, then, according to the well-known rule, it will perform double the space or double the distance in the same time.

If in a vortex in which the motion is greatest at the centre and least in the extreme circumference, there move two bodies at unequal distances from the centre, but so that each in its place is always at the same distance from the centre, or moves in a circle; then the squares of the periodical times of each body will be as the squares of the radii divided by their complements extending to the ultimate circumference. In fig. 1 (p. 106), let $dc=l$ or the length from the ultimate circumference; $ca=r$ or the radius of the same circle; $db=\mathrm{L}$; $ba=\mathrm{R}$; $da=z$, or the whole radius. In this case, the squares of the periodical times of the circle c, to the squares of the periodical times of the circle b, will be thus: $t^2 : \mathrm{T}^2 :: \frac{r^2}{l} :: \frac{\mathrm{R}^2}{\mathrm{L}}$, or what is the same, $t^2 : \mathrm{T}^2 :: \mathrm{L}r^2 : l\mathrm{R}^2$. The reason is, that the velocities at c and b in the figure are computed according to the general rule $l : \mathrm{L} :: c^2 : \mathrm{C}^2$, (observe t denotes the time and c the velocity), or $\mathrm{L}c^2=l\mathrm{C}^2$; therefore $c=\frac{l^{\frac{1}{2}}\mathrm{C}}{\mathrm{L}^{\frac{1}{2}}}$, =the velocity in the circle c; and $\mathrm{C}=\frac{\mathrm{L}^{\frac{1}{2}}c}{l^{\frac{1}{2}}}$, =the velocity in the circle b. If the velocities be divided by the circumferences of the respective circles, we then obtain the periodical

times. Instead of the circumferences, let the radii be taken, because they are in the same ratio with their circles; in this case $ac=r$, and if divided by $\frac{l^{\frac{1}{2}}C}{L^{\frac{1}{2}}}$, becomes $\frac{L^{\frac{1}{2}}r}{l^{\frac{1}{2}}C}$, which is the periodical time of the circle c; while the periodical time of the circle $b=\frac{l^{\frac{1}{2}}R}{L^{\frac{1}{2}}c}$. Instead of c, or the velocity in one circle, let us put its equivalent or its like $l^{\frac{1}{2}}$, and instead of C, $L^{\frac{1}{2}}$; in which case the periodical times are $\frac{r}{l^{\frac{1}{2}}}$ and $\frac{R}{L^{\frac{1}{2}}}$. Squaring these, the result is $\frac{r^2}{l}$ and $\frac{R^2}{L}$; therefore $t^2 : T^2 :: \frac{r^2}{l} : \frac{R^2}{L}$, according to the proposition. If the motion be least in the centre and greatest in the circumference, then the squares of the periodical times are as the cubes of the distances from the centre, or $t^2 : T^2 :: r^3 : R^3$. In the contrary case, however, of which we have spoken above, $t^2 : T^2 :: \frac{r^2}{l} : \frac{R^2}{L}$. But in or near the middle of the vortex L does not much differ from r, or $L=r$; and in like manner $l=R$. In this case or in the middle of the vortex, if instead of L we put r, and instead of l we put R, we have the forementioned proportion $t^2 : T^2 :: r^3 : R^3$. Nor does the computation in each case much differ, if the bodies are on each side almost equally distant, each from the centre of its own vortex; in which case l will not so much differ from R, and L from r, but that it may be almost substituted for it.

Let two circles be given in a vortex whose motion is greatest in the centre and least in the circumference, the ratio of the velocity in the two circles is required. By computation the velocities in those circles are as the rectangles of the radii and of the times reciprocally. For if $t^2 : T^2 :: \frac{r^2}{l} : \frac{R^2}{L}$ and instead of l we put c^2 or the velocity, its equivalent will then be $t^2 : T^2 :: \frac{r^2}{c^2} : \frac{R^2}{C^2}$. Whence it follows, that $c : C :: Tr : tR$. In the other vortex, however, in which the velocity is greatest in the circumference and least in the centre, the velocities are reciprocally in the subduplicate ratio of the radii, that is to say, $r : R :: C^2 : c^2$. If however in each case the body be in the middle of the vortex, both com-

putations coincide; so also will they if the two circles be at equal distances from the centre; for then $l = R$ and $L = r$ nearly.

In a vortex whose motion is greatest in the centre and least in the circumference, the centripetal forces are as the altitudes divided by the radii. Let v = centripetal force; then is $v : V :: \frac{1}{r} : \frac{L}{R}$ or $v : V :: lR : Lr$. The reason is, that the velocity near the circle c, or at the first altitude l, is $l : L :: c^2 : C^2$, according to the rule; or $Lc^2 = lC^2$ and $c^2 = \frac{lC^2}{L}$. The velocity is in the ratio between the radius and the centripetal force. The radius $= r$; hence $r : \frac{\sqrt{lC^2}}{L^{\frac{1}{2}}} :: \frac{\sqrt{lC^2}}{L^{\frac{1}{2}}} : v$, or $\frac{lC^2}{Lr}$ = centripetal force. Since C^2 is equal or similar to L, omit $\frac{C^2}{L}$, and we have $\frac{l}{r} = v$. In the same manner at the other radius or L, $\frac{L}{R} = V$; therefore $v : V :: \frac{1}{r} : \frac{L}{R}$. But in the vortex in which the motion is greatest in the circumference and least in the centre, the centripetal forces are reciprocally as the squares of the radii; that is to say $v : V :: R^2 : r^2$. In the former case, as we have shewn, $v : V :: lR : Lr$. In the middle of the vortex, however, or in two circles equidistant from the middle, there is not much difference between l and R and between L and r.

20. Finally, that the links of our argument may be duly connected, *it will be sufficient to shew the connexion of the second finite with the one preceding; inasmuch as I have already shewn the connexion of the one preceding, with the point.* For if there be a connexion of the second finite with the first and of the first with the simple, *it follows that there is a connexion between all the three, and of the last with the first.* That there is a connexion between the second finite and first substantial, appears from its origin; for it is from the first substantial alone that the second finite originated. It appears, also, from the manner of its origin; because it derived its existence from the first substantial, in the same manner as the latter derived its existence from the point. Consequently, there is a connexion between the three in regard to mode. But to speak specifically in regard to motion and situation; since the internal motion and state of this finite is the same as the motion and state of its antecedents, and the motion and state of the antecedent is the same as the motion

and state of those which preceded it, or of the points, there appears to be, in regard to motion and situation, a similarity between this finite and its antecedent, as also between this antecedent and its preceding simple; so that the motions of the first and third are proportional to each other. For instance; as the motion of the first is to the motion of the second, so is the motion of the second to that of the third; and so on in a continued geometrical relation: or as the axillary motion of the former is to its progressive motion, so is the axillary motion of the latter to its progressive motion. And if the progressive motion of the former were the same with the axillary motion of the latter, there would be a continued geometrical ratio between them; but this is not always the case. There is also, in regard to the power and quality of producing subsequent finites, a connexion between the second and the first. In fine there is, in regard to every one of its parts and modes, a connexion between the second finite and the first, consequently between the second finite and the point, through the medium of the first substantial.

GENERAL OBSERVATIONS ON THE COEXISTENT OF THIS FINITE, WHICH WE DENOMINATE THE ACTIVE OF THE FIRST FINITE.

In the present chapter we ought to advert to the existence of another entity; because it arises from the first substantial or least finite, equally with the second finite of which we have been speaking. This being the case, we here present our observations upon it; more particularly as this entity is the coexistent of the first finite.

At the commencement of this chapter it was seen, that as yet, in our nascent world, there was no other substantial beside the one which we have called the first; and that the second finite derived its existence from the first finites only by means of motion. Before however its existence was possible, I have supposed the existence of the contingent, that one substantial was proximate to another and that they were in mutual contact; whence there was a mechanical necessity that the finite ens

should coalesce into another similar to its first parent. In case, however, there should be no such contingent as that one pressed upon the other by mutual contact, I now observe, that there would, nevertheless, from this substantial arise a new ens, not so similar to the finite. Since, therefore, only these two contingents can be assigned, namely, either that the finites closely touch each other and are in mutual contact, or that they do not; and since I have stated that the finite came into existence only in the former case; it remains now for me to say what that is which proceeds from the first substantial, supposing the substantials were not in mutual contact but dissociated and dispersed. I observe then, that, in this case, there would naturally exist a certain new ens dissimilar to the forementioned finite; and since no third contingent can be assigned, we proceed to enquire what is this kind of ens which could come into the nascent world with its other coexistent and coeval ens.

We have then to demonstrate from the connexion between the existences of things, that the same cause must operate in the production of this ens, which operates in the production of the second finite: each proceeds from the same substantial; therefore each proceeds from the same cause. If one be a parent in which there is no diversity, then, by means of the same force and mechanism which it possesses within itself, it must generate both the one and the other: unless there were the same cause and the same substantial to produce, there must result some different entity; which is contrary to the tenor of our argument. The first thing, therefore, which we must presume in the connexion between the existences of things, is, that there is only one cause in one and the same subject, which gives rise to each production; since there is nothing else which can as yet be predicated of the substantial. It will appear in the sequel, that the same axillary motion in the substantial procreated this active, by the same proper force and actuality by which it created the second finite of which we have treated.

If there be a connexion between the things, it also follows, that what was produced from the same substantial and by the same cause, is similar in all the essentials of motion and figure; or, that the active is, in regard to its motion, figure, and numerous essentials, similar to its coexisting finite or finite

proceeding from the same origin. For if its origin and cause be the same, it follows that it is itself similar.

Now there is nothing which can produce anything dissimilar between the second finite and this coexistent active, beside the contingent of which we have spoken, namely, that the second finite took its origin in some volume of substantials which were in mutual contact with each other; but that the active existed from no such volume, of which the parts were in contact one with the other. The mode itself which generates the difference is only one. This mode can produce only the following result; that the coexisting finite shall consist of a certain volume of substantials confluent by their motion into some new finite, but that this new finite shall run not in the volume, but extraneously to the volume, without any consociates, into the same figure of motion. Since, therefore, the cases are only two, so also there is only one mode which can possibly vary the effect or occasion the finite to exist with several consociates or without them.

The origin of this ens is, therefore, extraneous to the volume of several; as is consequently this ens itself, which spontaneously runs into a certain gyre, and by its motion describes a certain surface, which consists only in the motion of one substantial: whence it deserves to be called an active, and indeed the active of the first substantial.

Unless there were two entities in the nascent world, one active and another passive, no elementary could be produced; as will be shewn in the sequel. In the present case, we have one ens capable of moving, another ens capable of being moved. One is an ens which acts; the other an ens suffering itself to be acted upon; from which two contraries may be compounded a third, which will be an elementary compound, and, together with its associates, will be capable of applying itself to every motion. Of this, however, we shall speak in the sequel.

CHAPTER V.

OBSERVATIONS SPECIFICALLY ON THE ACTIVE OF THE FIRST FINITE: ON ITS ORIGIN FROM THE FIRST SIMPLE FINITE; ON ITS MOTION, FIGURE, STATE, AND OTHER ATTRIBUTES AND MODIFICATIONS: SHEWING THAT THIS ACTIVE IS ONE, AND CONSTITUTES THE SUN OF OUR SYSTEM; THAT, IN LIKE MANNER, IT FORMS THE FIRST ELEMENTARY PARTICLES.

1. *That the active of the first substantial is only the motion of one substantial running into circles by means of which a surface is formed.* If the given contingent be, that the first substantials are not in mutual contact, then, in obedience to their conatus and inherent force, they run out into local motion. There is nothing to prevent them from so doing. The active, therefore, of the first substantial is no other than the first finite passing into a local motion. This is the reason for which we call it an active, and for which indeed it is so, inasmuch as it has a local motion; for active force consists solely of local motion.

2. *That the axillary, progressive, and local motion in a simple or point cannot be made a subject of investigation in any other manner than that of an unknown quantity in algebraic analysis, namely, by means of what is known; it must, therefore, be viewed through the medium of what is posterior and geometrical; and that from the axillary, progressive, and local motion, as given in the sequents, it may be concluded that there was a something similar in their first origin; and that the quality of the motions in the points may be elucidated by a similar analysis and mode of computation.* Inasmuch as in the simple there is nothing substantial which is moved, but nevertheless a something which

must be understood as being similar to motion and figure, we must assume it as an unknown quantity; in order that we may introduce it, together with known quantities, into our algebraical or geometrical calculations. The geometrical data, therefore, being considered as known, we may by an arithmetical and analytical computation arrive at that which is not geometrical, or which is unknown. In no other way can we arrive at a knowledge of the axillary, progressive, and local motion in a point. Assuming, therefore, that there are these motions in a point, it follows that every point possesses an active force; and that the aggregate of these points disposes itself by motion into a situation conformable to the similar motion and figure of each; and that it thus exhibits the first substantial, or its active, according to our description in the Third Chapter.

3. *If in the first substantial the points disposed themselves into a spiral situation, it follows by mechanical necessity, that this substantial must have an axillary rotation.* For these points could not be disposed into such a situation, unless they all conspired to a similar situation and figure, and were all so situated as to be constantly able to preserve their figure. Since, therefore, all are in such a situation that each spirates in a manner similar to the other, they hence, by their common effort, conatus, and force, mutually urge themselves into one common motion: this motion will be accordant with their situation, and consequently can be no other than the common motion of all the points, or of the entire substantial, round the poles or their axis. By spiral flexures round one pole, these points tend from the centre to the surface, in the same manner as they tend by spiral flexures round the other pole, from the surface to the centre. There is therefore, between the poles, an intermediate motion into which the points tend by reason of their situation and effort; namely, a motion according to the equator or around the axis or centre of the equator.

4. *If, in the first substantial, the points dispose themselves into a spiral situation, it follows by mechanical necessity, that this substantial is progressively moved in accordance with the situation or order of the spires; that is to say, there is in it a motion of the parts or a progressive motion.* For all the points are in the situation and figure of their motion, and linked into spires by a

perpetual connexion and series. Since there is constantly in every point a something actual, one point must necessarily act and press upon the other and proximate; consequently upon the whole series, upon all that are connected with it, or contiguous to it. And since there is nothing in their figure to prevent their being moved, there consequently results a progressive motion; which can be no other than such as is accordant with the preservation of a similar figure and situation of the parts. The motion, therefore, is toward the consequents [*in consequentia*]; or accordant with the circles of all the spires, or with the general situation.

5. *That the centre of gravity is not in the middle of the substantial, but near its middle; and that it follows the progressive motion of the parts and of the figure.* Inasmuch as its situation or figure is spiral, its centre cannot be in the middle: it would be in the middle if its situation or figure were simply circular; if, therefore, we grant that its situation or figure is spiral, we must also grant that the centre of this figure is at a distance from its middle. And inasmuch as they are points or individual parts which compose its situation or figure, it follows that this centre is its centre of gravity. Since the centre of gravity is not in the middle, but on one side; and since the points or individual parts are in progressive motion; since, also, in this progressive motion, the same figure of situation is always preserved; so it follows, that the centre of gravity likewise progresses, and that this progressive motion of the centre of gravity is the same with that of the whole figure or of all the parts.

That the centre of gravity is in the plane of the ecliptic, not in the plane of the equator; and that its progressive motion is secundum consequentia, *or according to the ecliptic of its figure.* Since the centre of gravity exists by reason of the spiral figure and situation, it must invariably keep in the tract of that figure; and since this tract is the same with that of the progressive motion, and is thus in the plane of the ecliptic, by which all the spires are bisected between the poles; the centre of gravity is in the plane of ecliptic, and not in the plane of the equator. Hence the centre of gravity moves on with the current of the parts [*secundum consequentia*], or according to the ecliptic.

6. *That by reason of its axillary motion, there is an effort in*

the whole compound toward a second or local motion; and consequently that this second or local motion is in accordance with the motion of the centre of gravity. If the centre of gravity be not in the middle of the compound but on one side, the compound gravitates in the direction of this side; and, in the point where it is heaviest, has a tendency to fly off in the direction of a tangent. The case is the same as if a circle were formed heavier in one part than in another, and then made to revolve round its axis; in which instance all the other parts of the circle will gravitate toward that which is the heavier; and hence, were the circle at liberty, it would fly off in the direction of the tangent to the heavier part. Inasmuch, then, as the centre of gravity follows the general or axillary motion of the whole compound, and cannot pursue a rectilinear course in the direction of the tangent; but, in consequence of its rotation, moves in accordance with this tangent and its continual circumvolution in a circle, (that is to say, the same revolving motion into which the centre of gravity is carried); it consequently describes a circle accordant with its motion and velocity.

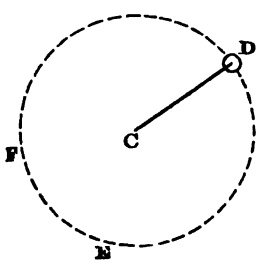
Since the centre of gravity has not only an axillary rotation, together with the compound, but likewise progresses in its plane or in accordance with the ecliptic; the local motion describes not only a circle, but also a superficies. Since the progressive motion is slower than the general, and advances only one step while the general motion accomplishes a whole circle; and since the centre of gravity progresses in a similar manner, and in the plane of the ecliptic, it follows, that at every circumgyration it makes some advance, and in its gyration moves itself sidewards every moment; and thus constantly makes some other and new section and node with the equator. It consequently moves its folds spirally; and these taken collectively form the surface.

7. *That all the actives of this kind flow with one and the same velocity, neither less nor greater; that they always describe similar gyres and circles; nor can they form any either less or greater.* Inasmuch as the active runs out according to the determination, direction, or motion of its centre of gravity, and according to the tangent of its motion; it consequently cannot do so with any velocity greater or less than is proportioned to the force given by the axillary rotation. If the axillary rotation be swifter,

then its power of flying off becomes greater, and consequently it makes a swifter excursion; if the axillary rotation be slower, its excursive motion is slower. The force itself is more or less active according to the greater or less degree of velocity. If, therefore, the axillary rotation of the compound give activity to the force; it follows that, since the velocity of the axillary motion is the same, since the distance of the centre of gravity from the middle is the same, since the figure of the compound is always the same, the active we describe cannot flow into circles larger or smaller than such as are proper to it, nor with any other velocity than such as is similar to that of the generative and directing force. If the velocity be greater, the circles formed are smaller; for by a greater velocity the gyration is completed the more quickly. The contrary is the case, if the velocity be less. If the velocity be the same and the distance from the centre of gravity to the middle be the same, then perfectly similar gyrations will be performed.

8. *That in this active there is nothing substantial, with the exception of that only which is circumfluent; and nevertheless that a surface may be represented by motion, just as if it consisted of mere substantials.* A representation by motion of what is continuous is a very common occurrence. For if a corpuscle, moving in any given direction, describe a line or a circle; a line or a circle becomes immediately represented by this motion; and the continuity, coherence, and contiguity, appear the greater in proportion as the motion is swifter, or as it is more repeatedly present at any given point. Thus (figure 4), if the little ball D be whirled round by the radius proceeding from the centre C, as by a sling, a circle will be represented; although in the circle there would be nothing substantial but the ball itself. The point where the ball is present, is perpetually substantial and material. If the velocity be so great that its progressive gradations and moments are imperceptible, it follows that in every point of the circle the ball is as it were present and perceptible. A

Fig. 4.*



* In the original, plate I. fig. 2.

resemblance to a substance may therefore be produced by motion.

9. From these observations it follows that *in the surface of the active, there is no point which can truly be called substantial, beside the one where the fluent substantial is itself present.*

10. *That nevertheless this ens is most perfectly active, and also endowed with a considerable power of acting upon the proximate finites.* Force [*vis*] of acting accompanies local motion. In local motion itself resides all motive and active force; and without this motion it is impossible to conceive the existence of any living force. Now, since an ens of this kind consists only of motion, so that the whole of its configuration is nothing but motion, it follows that the whole of this configurated ens is most perfectly active. Acting force is greater or less according to the degree of velocity. In a less velocity, which is as it were a less degree of local motion, the force is less; in a greater velocity, the force is greater. If, therefore, in a moving body the velocity is the greatest possible, then its force [*vis*] of acting will be the greatest possible. If the ens which is acted upon and which thus acts, possess any weight, then its force is augmented in proportion to its weight; although the degree of velocity is enabled to supply what is deficient in mass. If the body moved be so acted upon as to be itself enabled to act in every direction, on every point and at every angle, it possesses a more multiplied and larger force than a body in motion, which is able to act only on one part and at one or at few angles. Let us assume some real surface consisting of mere finite entities, let this superficies be assumed as perpetually fluent, and it will in like manner be possessed of an active force; but one which is determined only at one angle, namely, the angle of its contact with the ens upon which it runs; it acts only at one part or similarly in every place, and it may therefore be said to act with a simple force. The active, however, of which we before were speaking, has no determinate force of acting; but is enabled to act, at all angles, upon each finite it meets; it can act, for instance, at a right angle, an oblique, obtuse, acute angle, or perpendicularly; thus at all angles and at all parts of the body. There is no point in the body opposed to it upon which it cannot act at all sines and angles; nor, in any body that

meets it, is there any angle upon which it may not act in a similar manner, whether with its whole force, or with the half of it, or whether that force be greater or less. In fine, it is enabled to run against [*incurrere*],* to run toward [*occurrere*], or to come into collision with any other body. There is nothing in any action, which it does not possess. For the ens which is fluent is only one, and nothing is present which can detract anything from its determination: everywhere it traces its own periphery; and its action upon another corpuscle is according to the situation of its periphery, and the situation of the corpuscle upon which it acts. And since it is capable of being in every situation, so in every situation it acts according to its angle, upwards, sidewards, and downwards. In fine, there is nothing in any activity which cannot be present in this active. The superficies therefore which is thus formed by the motion of one ens, is a real and active ens of motion.

11. *That no where in this superficies can there be conceived a point, which is not acting, although at distinct moments.* For though the entire superficies consists only of one point or substantial, yet by motion it is always as it were present in every imaginary point of its superficies; and hence every point of this surface is acting, but only at distinct moments, for it cannot be in every point of the superficies at one and the same instant. In proportion as its moments are fewer or its velocity greater it is more or less active.

12. *That in respect to this active, finites concatenated in a series or in an aggregate, are passive.* For a finite concatenated with others in a series, or in an aggregate, possesses none but an axillary and progressive motion; no local motion, which yet is the only active one except in a series. For without local motion no activity can be even conceived. The finite therefore is passive in relation to the active, which has none but local motion. Every finite is also an active, in so far as it has an axillary motion and consists of individuals which are in a perpetually progressive motion, and which thus have a force of acting.

* Corpus unum *incurrere* dicitur in alteram, si vel in quiescens, vel motum, in eandem partem impingit. *Cosmologia Wolfii*, 238. Corpus unum dicitur *occurrere* alteri, si ambo moveantur in partes contrarias, et in se invicem impingant. *Ibid.* 329.—*Translator.*

However, from this power or force of acting, (inasmuch as the finite, when in a series or aggregate, is, as it were, under restriction,) nothing proceeds but the ability, inclination, and effort to actuate itself in some different way, or to pass into a local motion; moreover this force is directed and determined to the proximate finites, in order that a new finite may be procreated. So far, therefore, as it is concatenated with, or tied to anocher, it is passive and not active.

13. *That this superficies may, according to the different degrees of velocity, be represented as more and more like a continuous and finite superficies.* If the velocity be the greatest possible, the substantial fluent in the superficies is present at any point within the least possible time; and is hence more frequently present in any point of the superficies, than if the velocity were less; consequently the figure or surface so represented by its presence, differs from a continuous surface or figure only in regard to the intervals or moments of its presence. The more quickly it is present, the more perfect is the simulation of what is continuous and *vice versa.*

14. *That this superficies has no real dimension, but that it may be called an apparent, imaginary, and mere surface.* It has no length, because it consists only of one substantial; it has no breadth, except in the place where the substantial is: in the infinite number of places in which the substantial is not present, it is destitute of breadth; it has therefore no dimension except in one point, and this one point does not of itself constitute a surface. The surface, therefore, is void of all breadth. Much less has it a third dimension or depth; for of this it is manifestly void; except when, by its eccentricity, it is translated from one place to another, so that, by means of these translations, the surface may apparently occupy space. On this subject, however, we shall speak more at large in our observations on the fifth active. Neither has the surface any real centre, for since the surface is not real nor always in the same place, neither is the centre; unless it be so considercd relatively to the surface which it describes by its fluxion.

15. *That, when present, it acts perpetually upon every finite: that by its presence it is enabled to act upon the finites and to dispose them to a certain motion, situation, and figure.* In the

sequel it will be evident, that it cannot act upon actives flowing in juxta-position with it; or that it is rarely in contact with them, so as to be able to exercise upon them any action. Upon every finite, however, which is present, it acts, and by its motion disposes it into a situation. For since it is able to act in all directions, both in a right line and obliquely, upwards and downwards, it follows that whatever comes in its way it impels and urges in a different direction; for since it is perpetually acting and soliciting, it will at length urge the body to some place where it can no longer thus be acted upon, and where it may remain free from its impulsion and action; that is to say, it will urge it into some situation and figure, of which we shall speak in a following chapter. It is however to be understood, that a single active cannot impel any finites into any definite situation; this can be done only by a space consisting of several actives.

16. *That several actives of this kind may be fluent within one and the same space, without any congression or conflict.* For if several and innumerable may gyrate in the same space, one cannot possibly come into contact with another till after an infinite number of revolutions and periods. Imagine how many points there may be in one surface, while in all these points there is only one substantial, or one point which is substantial, and innumerable others which are destitute of it, before it can present itself in them. If therefore there were innumerable points in one space, they could not come into contact with each other, unless two substantials were present in one and the same point; an event which could not take place among an infinite number of points, except after an infinite number of returns to the same place or point of the surface. No such collision can take place, as that one shall run up against the other which precedes it; because the velocity of all is equal and the circumference described by all is equally distant from any given centre. If the motion be equal, one cannot overtake another; or, by help of a greater velocity, arrive at the place of another: all however numerous will maintain their orderly sequence: so that one will not run up in collision against another. Consequently one will not easily meet another and occasion a conflict; because, as we have said, it can be present at one time only in

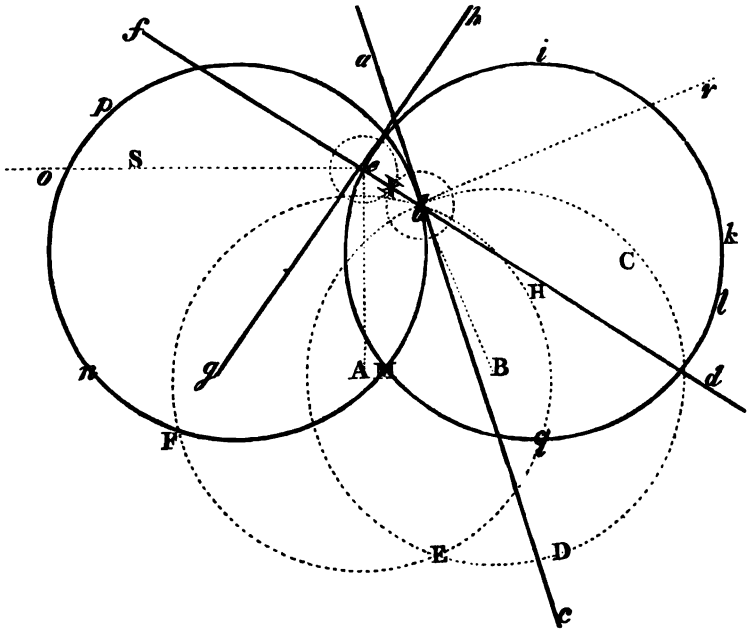
one point of the superficies. There may be an infinite number of places occupied by others; these places may be left vacant, until the point return, after having passed through a long series of circles. In fine, if all the points have the same velocity and the same circumference; and if the circumference consist of only one substantial; if all observe the same moment in returning to the same place; it follows that a case of contact can seldom take place, but that all the actives must perform their gyrations without experiencing any retardation from others flowing with them in the same space.

17. *That several may simultaneously adapt themselves to any angle and space; and that, taken collectively, they may represent any figure.* For if several may, in one space, perpetually perform their gyrations without impinging upon another, running counter to it, or in any way coming into collision with it; so may they at the same time apply themselves at every angle, and to every space. If by impinging upon or by collision with finites, they are sent in a different direction or to any distance from them, they immediately, at the same distance, describe the same circumference, not a new one; for in whatever place they are, they are always in their own circumference, whether it be at a greater or less distance from the finites. They are in no other place than their own circumference; for they cannot possibly run out into any other than their own, or the one into which they are perpetually carried by their own inherent and natural force. If there are several actives of the same kind in one space, these imaginarily occupy the space by their formal and apparent circumferences; and in these there is no place or point which they do not touch and as it were occupy.

With regard to our other observation, that, when taken collectively they can represent any figure; this is evident from the following circumstance, that all these circumferences can be present in one space, and this a very small one, and that *one periphery may apparently as it were cross and cut another; that near one surface there may appear innumerable others, crossing as it were through that one;* as may be seen in figure 5, where we may perceive one surface crossing over the other, according as the centre of each is within or without the surface of the other. For were the surfaces real and consisting only

of finite entities, then the nearness of one circumference to the other would be only that of contact; and in one space there

Fig. 5*



might be as many as could find a place in it. With these actives, however, the contrary is the case; for they do not constitute any real superficies, but only one that is apparent and figured out by motion. Surfaces of this kind may be without number, for there is between them no conjunction by contact; hence the surface of one may be carried through the surface of the other. Innumerable surfaces may, as it were, be fluent across one. The smallest part of one and also the largest may extend beyond the surface of another, and may again withdraw itself within the interior of this other. In fine, there may be represented in one space as many surfaces as may, in the chart of a circle, be described from an infinite number of centres both within and without the circle of the other. For we are at liberty to assume their centre wherever we please. Since therefore these

* In the original, plate II., fig. 10.

surfaces may be described from innumerable centres, (whether these centres be assumed as within, or in, or without the surface of the other,) it follows that, when taken collectively, they may not only occupy a small space but may also collectively represent any figure.

18. *That several in one space can rarely be in contact with each other, unless they are in too considerable abundance.* For if the abundance be so great that one fluent is obliged to press against the other, then may they meet together [*occurrere sibi*] and coalesce into one finite. Of this subject, however, we shall speak in our observations on the third finite.

19. *That if they meet each other, they nevertheless continue the same superficial gyration.* Actives, wherever they are, are in their own periphery. No acting force urges them into any other periphery than their own. If they become diverted from their place by counteracting any finites or consociate fluents, then they are deflected into some other place; but still always into one in which they continue to describe their own periphery; because wherever its substantial is, there also is its periphery; hence we cannot say that it has its periphery in any fixed and determinate place. In figure 5, if *e* and *b* be two substantial actives which meet each other in X, each immediately is terminated in the direction of the tangent of their concurrence; each also may change its place; still they continue to gyrate, or to be in the same place; but to gyrate as it were from a different centre; for the substantial *b* may run out from the same place *b* into the periphery CDE, into the circle HEF, or into the circle MF*p*, or into an infinite number of other circles, according as it receives its direction from any other active or finite meeting it.

20. *That innumerable actives may occupy an exceedingly large space. That they may occupy a space as large as the solar, and much larger.* That the solar space is occupied entirely by these actives and by those of the second finite, will be explained in the sequel.

21. *That they may likewise be fluent within an extremely small space, within a surface consisting of finites.* We have above stated, that these apparent surfaces may occupy a small space;

that they may exercise their force upon the contiguous finites; and impel and dispose them into a certain regular situation. They may flow, therefore, within a surface consisting of finites.

22. *That several collectively in one space possess a greater force of acting than a smaller number.* For from several in one space exist several surfaces: the motive forces and actions are as it were more in number: one and the same body may be more frequently acted upon by them; by one directly, by another obliquely; that is to say, one body may be acted upon by several in a variety of ways, more frequently and as it were continually. The more numerous, therefore, are the actives, the greater action and force can they simultaneously exercise upon all the bodies they meet, so as to leave not one of them intact.

23. *That this active arises from the same force and cause from which arose its coeval or coexisting finite.* The power of this substantial to pass into gyration, arises, as we have frequently said, from the internal force or motion of the points. It is from the same cause, also, that several points pressing upon each other by mutual contact, give rise to a certain new finite. For one substantial tends to a periphery similar to the periphery of this active; so do a second, a third, and all the other contiguous and innumerable ones; if therefore all aim at one and the same periphery, if also one be contiguous to the other, then ought all collectively, in consequence of this motion, to be confluent into such a situation as is shewn to be assumed in the case of the second finite. Hence the cause of the second finite is the the same as the cause of this active. Hence both are called coeval and coexistent; since they proceed from the same origin and the same cause, and may come into existence at the same time and at the same moment.

24. *That the apparent surface of the active is similar to the surface of its coexisting finite.* For the cause impelling both the one and the other into motion, is one and the same; and hence there exists a similarity in the surface.

25. *That the circumstance of the active running into circles, is favorable to activity only by enabling it to be everywhere present, and to act everywhere; but the circumstance of its exercising*

a force upon the bodies it meets, arises solely from its velocity and mass.

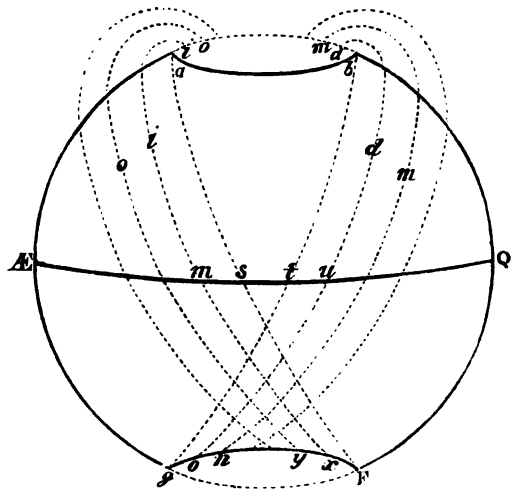
26. *That it was capable of existing before its finite, and of being the cause of the contingent that second finites arose.* In our series of first principles, there is nothing more difficult than the knowledge of the causes from which contingents have been provided. Indeed, the cause itself lies in the first motion; but, inasmuch as it is contingent, and there may be a great variety of contingents,: we must consequently seek for the first cause from the first motion; and not only the first cause, but also all the others. We cannot penetrate, therefore, into the causes of contingents, except by means of a knowledge of the successive existence of things; and if we are without this knowledge, we are unable to divine the nature of the contingent required for a thing to exist in such and in no other manner. In our nascent world, it as yet seems possible only for the two contingents before mentioned to exist; consequently we may arrive at the causes of those more easily than at the causes of subsequent contingents. With regard, therefore, to the cause of the contingent, or existence of a second finite, this we may in some measure divine from the existence of the first substantial. For if there were one only first substantial to occupy the nascent world, it follows that all the substantials must have been so contiguous that there was no space left for them to run out into their apparent peripheries. Yet reason dictates, that, if this were the case in one place, it was the same in another; because the whole of that space was of necessity similarly full. But inasmuch as, according to our hypothesis, actives had proceeded out of it; it follows that the substantials were not more contiguous to each other than would allow of the existence of actives; if therefore they were not contiguous, it follows that, in the first place, actives existed, and that after these, were necessarily produced finites. For actives occupy space; they perpetually act upon the adjacent finites, urge, solicit, and impel them from place to place, until the finites have betaken themselves to some quarter where they are exempted from the influence thus exercised upon them. If therefore the first actives have already arisen, and if the space be filled with actives, it follows that the substantials, flowing as yet into no

gyre, become more and more confined, so as gradually to be rendered less able to pass out into gyrations and become active; this confinement continues to increase till by contact, one presses upon the other and they are thus enabled mutually to congregate into one finite and new corpuscle.

27. Inasmuch as the centre of gravity remains always at an equal distance from the middle of the substantial, so long as the same velocity of progressive and axillary motion remains among the fluent points, or so long as the same figure of motion continues; *therefore also the substantial itself, continually running out into spiral circles according to its centre of gravity, can do no otherwise than keep at a certain distance from a given centre, or always describe the same equal periphery and surface.*

From figures 6, 7, 8, we may see the figure which the fluent substantial must describe, and the circles by which it

Fig. 6.*



forms its apparent superficies. It can describe only a larger circle, because it proceeds from the margin of one pole to the margin of another. Thus Fig. 6, at *g*F and *ab* are poles, *ab* and *g*F being polar circles. The circles which it describes are *gb*, *od*,

* In the original, plate I., fig. 9.

nm, &c., from the lower pole to the upper. From the other side of the upper pole it runs back by similar circles to the lower.

Fig. 7.*

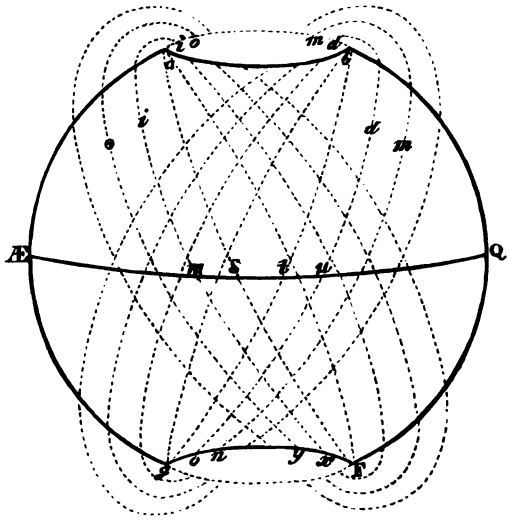
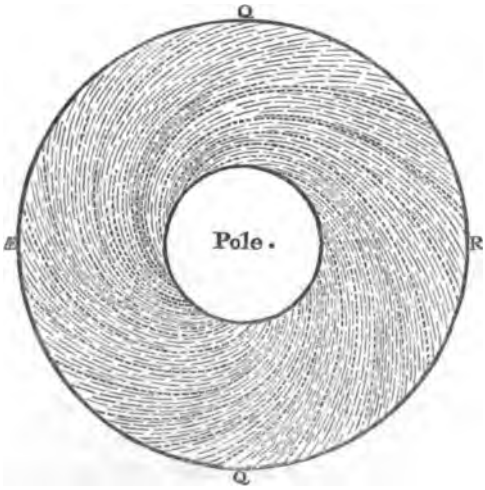


Fig. 7 represents the same at each pole. The motion of this active is represented also in figure 8; where ÆQR is the equator; the

Fig. 8.*



pole, which is made conspicuous, being situated in the middle.

* In the original, plate I., fig. 9.

Thus are formed larger circles, meridians, and latitudinal circles. If these are bisected at right angles, we obtain the ecliptic.

28. *With respect to the force acquired by the velocity,* it is evident from the mechanical laws of motion, that the quantity of the motion is produced from the mass multiplied into the velocity, and that the impetus is in the ratio of the mass and velocity. Hence a body moving rapidly has a greater power of acting or pressing than a body moving slowly. So that if it be the same body in motion, the force is proportioned to the velocity. But inasmuch as the force arises in like manner from the substances, and a heavier substance with the same velocity has a greater force and impetus than a smaller one, hence a smaller or lighter substance may have the same force as a larger, if the velocity in the smaller be proportionally greater than it is in the larger substance. And although this substantial which is moved be the smallest, nevertheless, on account of its immense velocity which is of the first degree, this smallest substantial must likewise possess a force proportioned to its velocity.

29. Let us now come to experience. *But here again, since we are destitute of experience, we have resorted to the formation of principles; for in things so minute the senses can have no experience.* These actives transcend the sphere of the most subtile sense; for they act upon those more compounded particles, whose motion being conveyed by contiguity to the particles constituting a still crasser element, form at length a communication with the organs of the senses. We thus see as it were from afar, but nevertheless through the medium of reason, that there are entities in which resides all possible force of activity. When we arrive at the actives which are more compounded and which constitute our elementary fire, we may then for the first time physically and geometrically demonstrate, that it is in this, or a similar action of the actives, that all igneous force consists. Of this subject however we shall speak in the sequel.

The fact that a body may by internal motion be made to pass into another motion, is one which experience every day testifies. Every being in the world which possesses animation, whether man or brute, is impelled or actuated only by internal motion. The various members, such as the arms, feet, &c., follow, together with the whole body, the motion of the muscles; the muscles

follow the motion of still smaller organs, or it may be still smaller muscles; the organs follow the motion of others, which are most highly subtile, and which are determined by the soul through the medium of the will into act. Thus the first motion comes from the most subtile, and proceeds gradually to the more and more compounded; until the entire machine passes into motion. Hence arise the mechanical imitations of those who have contrived automata or human figures attached to clocks; and which are internally supplied with motive powers and tendons, that not only move their arms and feet but put the whole machinery into a local motion. What is more common than for a corpuscle to be put, by its internal motion, into a rectilinear or circular motion, in case the centre of motion within be not in the centre of the corpuscle but at a distance from it? If in the case of a watch, the chain be snapped by which the elastic power of the spring is restrained, the machinery is thrown into a motion, not only hurried, but circular and local. These are things which are too well known to require further observation.

30. By way of conclusion we will now briefly speak of *the connexion between this active and the finite*. This connexion has been indicated throughout the whole of the description of this active. It has been shewn, for instance, that this active derives its origin from the first substantial, from its internal motion, and from the power or force [*vis*] of this motion, by a perfectly regular figure of fluxion. And since the second finite, which is the coexistent or coeval of this active, has been shewn, in our preceding chapter, to have derived its origin from the same cause, and its connexion with the first substantial has been demonstrated, so also from the same demonstration follows the connexion of this active with the first substantial; especially as the only difference between the two relates to the contingent of each in regard to its origin.

Although, however, the second finite and the active proceed as twins from one parent, still they are both of a contrary disposition. The one is, as it were, most inimical to the other. The one is most highly active, the other is most highly passive; so that they cannot mutually consort and associate with each other in the same place. Hence in the following chapter we

shall have to shew in what manner they ultimately come into concord; how one consociates itself with the other, so that both can be in the same place and live one common life. Let us however leave this Proteus or Vertumnus of ours, that is to say, the active, which is able to convert itself into all shapes, and let us proceed to ulterior subjects; first premising however a few observations on the active of the point.

WHETHER THERE IS ANY ACTIVE BELONGING TO THE POINT; AND IF SO, WHAT IS ITS NATURE?

We have already spoken of the active of the substantial, or of the one which had proceeded from the first substantial. The question now is whether we may presume that any active proceeded from the point. On this subject we observe, that from the same argument used in shewing that an active proceeded from the first substantial, it may be shewn also that an active proceeded from the point. In both there is the same kind of motion. In the point there is a spiral motion from the centre to the surface, an axillary and progressive motion the same as in the substantial; by parity of reasoning we may infer therefore the same cause and effect. Hence it may be affirmed without any room for doubt, that the point may become an active in the same manner as a substantial; but inasmuch as in a point nothing exists but what is simple, and which therefore escapes all geometrical apprehension; inasmuch also as there is nothing in it which can be presented to the idea by lines, but only by way of analogy with geometrical lines, I have purposely omitted all description of its active; although it must be acknowledged that the point may become an active in like manner as the first substantial.

From analogy and similitude with the active of the substantial we may in some measure conceive what is the active of the point, namely, that it is a point impelled into motion by its own internal force; and indeed into concentric spiral circles, by means of which a most perfectly exact superficies is formed. Still however we can conceive of nothing substantial in this active besides motion; inasmuch as the point cannot be said to

be substantial, though by the highest degree of motion it becomes as it were substantial. The motion of this active however is almost pure motion, and consequently surpasses every degree of velocity. It may thus be said to be the most perfectly active; because this motion, which is almost pure and surpassing every degree of velocity, seems capable of imparting a substantial virtue to its simple; whence it follows also that this point, in consequence of its motion of indefinite velocity, can be present as it were in any part of its surface in an instant. Moreover of this active it may be said, that it has no dimension; neither breadth, nor depth; that an infinite number of them may be present in one space; indeed that they fill all space both the least in the world and the greatest; so that it is, as it were, an ens everywhere present, filling the whole mundane system in its smallest spaces; in consequence of which there cannot be said to be any vacuum, for that whatever space intervenes between the most minute entities may be occupied by this active. That these actives may in like manner be fluent without encountering or interfering with each other. That they may represent any figure, and may accommodate themselves to any angle; not to mention innumerable other things of which we have spoken in our observations on the active substantial, and which, on account of the simplicity of the point and the purity of the motion, cannot be geometrically conceived. Inasmuch therefore as things which are so near to what is infinite, and which as it were derive their origin immediately from it, are remote from all geometrical and finite apprehension, we must pass on to the mechanical part of the subject, and to the contemplation of our nascent world.

CHAPTER VI.

OF THE FIRST AND MOST UNIVERSAL ELEMENT OF THE MUNDANE SYSTEM, OR THE FIRST ELEMENTARY PARTICLE COMPOUNDED OF FINITES AND ACTIVES; OF ITS MOTION, FIGURE, ATTRIBUTES AND MODES; OF ITS ORIGIN AND COMPOSITION FROM THE SECOND FINITE AND THE ACTIVE OF THE FIRST FINITE; OF ITS CONSTITUTING THE SOLAR AND STELLAR VORTICES.

Thus far in our world we have two kinds of particles; the one most highly active and endued with all possible motive power [vi]; *the other altogether passive, and endued neither with motive power nor with local motion; whence also the one is plainly contrary and most inimical to the other.* The active always acts and impels [*incurrit*]. The passive always suffers and resists. One is most perfectly mobile; the other in its place is, in regard to local motion, inert. The question therefore is, what can exist from two entities so contrary to each other? For one cannot as yet be in the same place or space as the other: the one flies away as it were, while the other pursues. Consequently they cannot be in the same world, unless they are so separate that the passives may occupy their place and the actives theirs.

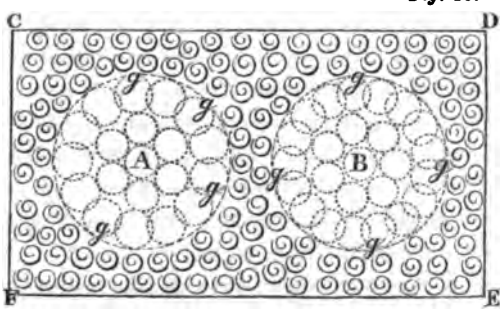
Before, however, anything elementary can exist, it is necessary that in the world there should be two principles, one active and the other passive: one which is perpetually in local motion, another which is not in local motion. Without these two principles no third can be produced which shall partake of the active and of the passive; in a word, nothing natural can come into being. For nature is that force which bodies possess of acting and suffering, in conjunction with the potency and vis of inertia.

Unless the active were a something separate, the passive a something separate, and both together constituted one body, nothing could be obtained which would be in agreement with nature. From pure finites proceeds nothing but what is similar to them; from the actives of the first finite, nothing but what is active; there is need therefore of two to the production of natural bodies.

Since therefore there now exist in the world only these two bodies which are so inimical to each other and so separate, and since in the one we have the highest *vis agendi* and activity, in the other the highest *vis inertiæ* and passivity, *we cannot possibly conceive them to be so separated, but that they must unite into one body*. For if the actives perpetually act, and the passives perpetually suffer themselves to be acted upon, there must necessarily arise a third body, so that the actives may always be enabled to act and the passives to be acted upon. For if one kind perpetually impels the other, and urges them at every angle into every place, it at length urges them into a situation in which they are exempt from all the influence tending to remove them further out of it.

Since therefore the one does not cease to act and the other to be acted upon, we may proceed, before each comes into the situation suited to its action and passion, to enquire what this situation or figure of situation may be, so that each may remain in the space of this figure and the force of each also continue.

Fig. 10.*

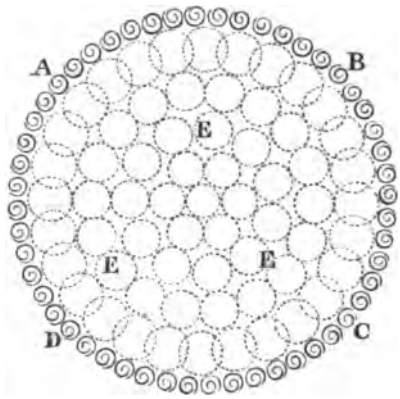


Let A and B be spaces filled with pure actives, around which are finites or passives. Since the enclosed spaces A and B do

* In the original, plate II., fig. 11.

not cease to act, till those which surround them are reduced to such a situation as to be enabled to perform one common motion in one and the same space, it follows that the figure which results is similar to fig. 11; the internal space of which, or EEE, consists of actives, and the external surface ABCD, purely of finites.

Fig. 11.*



We may also assign a mechanical reason for the existence of such a figure, resulting from the conflict of two entities so different from each other. For if (fig. 10) the space AB, consisting of pure actives, perpetually act upon the surrounding finites g, g, g, g, these surrounding finites must necessarily be put in motion round this active space; if they are put in motion it must be such a motion as accords with their figure, in passing into which one follows the other in a contiguous series. This motion round the active space cannot be any other than one which produces a spiral and circular disposition. How it is that such a motion accords with the figure of the finites, will be shewn upon mechanical principles in the sequel.

Wherever therefore there exists a small volume of this kind, consisting of actives and passives, there must necessarily result such a situation as accords with the nature of each; so that in this situation and space each shall subsist according to its own proper force and disposition. Thus it is that these twin-born entities, which are so inimical to each other, coalesce into one figure; although previously to the existence of this figure or situation they were perfectly separate.

By means of this new figure there is thus a connexion of each with the first substantial from which they derived their origin. For if from one ens there exist two which afterwards combine into one, then by this one both are connected with the first.

* In the original, plate II., fig. 12.

2. The particle thus produced I call the first elementary particle; because it is compounded of two, one active, the other passive. From these two the particle derives that elementary nature which is the origin of all the mutations which succeed before the world comes into existence. In order however to arrive at a right knowledge of this particle, we must have recourse to a definition. It may therefore in general be defined as being *the first elementary particle compounded of the second finites and of the actives of the first finite, possessing a perfectly yielding and elastic superficies.* Its other essentials follow from these; we must therefore treat of these separately.

3. *It is an elementary particle compounded of the second finites and of the actives of the first.* For the actives cannot of themselves constitute any volume, because they cannot be in contiguity with each other; for one cannot be in contact with the other; though one superficies may pass through another promiscuously, and though, as occasion may happen, there may be in the same space either more or fewer; besides which their superficies must be lessened. For the surfaces of these actives are only images, representations, and ideas of surfaces, of which there may be in one and the same space a greater or less number. Hence they do not constitute any volume, but only occupy space; provided there be surrounding finites to enclose the space. This space may be called an active space, or a space of motion. But there is no space which is contiguous or full of contiguous particles, unless so far as it terminates in the finites which surround it. Hence we arrive at a boundary of space, yet not resulting from the actives, which terminate nothing; but from the volume of the finites which surround them. This particle therefore consists of second finites and the actives of the first finite.

4. *That the second finites constitute the superficies, and the actives of the first finite occupy the internal space.* In no other way can they combine into one particle than by that of a situation in accordance with the nature of each (that is to say, with the motion of the active and the inertia of the passive); the actives occupying the internal space, and the passives forming a certain superficies round it. Thus may the actives, together with the passives which are around but apart from them, flow as

it were naturally into a certain superficies. The mechanical principles by which the finites suffer themselves to pass into these superficies will be explained in the sequel.

5. *That the superficies of this elementary particle is held in a state of suspension and equilibration by these two forces.* If there be motion, then nothing which is continuous can be produced without equilibrium. Equilibration is the principal mode by which two things in motion can be kept in perpetual conjunction. It is by equilibrium that they come into that situation, and by equilibrium that they are preserved in it. If this equilibrium be not most perfectly exact, the bond of connexion is broken, and the composition, as such, perishes. All concordance therefore, consentaneity, and unanimity, is the result of equilibrium. On the most perfect equilibration depends the perpetual preservation of situation and figure. Equilibration is the third or fourth analogue or proportional which results from the ratio of motion in two or more bodies. *A product of this kind cannot be obtained by the analogies of the antecedent motions except by means of space, extense, situation, and figure; all of which are presented if equilibrium be obtained.* The essentials therefore of equilibrium are the same with the essentials of two or more motions from which is obtained a product which exists only from essentials that as yet have no existence, nor indeed do exist until the equilibrium be obtained. In two motions there are present potentially extense, space, situation, and figure; but yet these do not actually exist till each motion proceeds to its equilibrium. To this it proceeds by figures, spaces, and situations; yet it cannot stay in any space, figure, or situation before it arrives at its ultimate or true equilibrium. Now it is first in this elementary particle that the essentials of equilibrium are present. For there is space, which is that which the actives and finites both together occupy; there is expanse or surface, which is that which the finites form; there is situation of parts, and in like manner, figure. In regard therefore to the equilibration of the surface, we observe that it cannot subsist except between two forces in such a manner, that there shall be as much pressure on one side as on the other. Unless there were an action of this kind on the extremely thin surface of bubbles, they could not subsist in the air. Unless there were equili-

brium of pressure on all sides, no vapor could retain the superficies of its particles, nor ascend into the upper regions of the air without being dissolved; no liquids could be formed by the fire into superficial expanses, and be wafted into the atmosphere; and here be it observed, that the superficies itself is intermediate between the force pressing from without and the force pressing from within. There could be no circular cavity or spherical expanse in fluids, unless there were within an equability of pressure all around. There could be no convexity, unless the reaction on one side corresponded to the action on the other. Convexity itself is a sign of a perfectly equal pressure on both sides. In this manner then is acquired the equilibration of the surface; in this manner may one surface be continuous, and receive and preserve a certain natural situation of its parts. With regard to internal force, this we find in the enclosed active space. If this space consist of mere actives which continually act, and which are also capable of acting in every direction, we are hence supplied with a force on one side of the surface to which some force on the other ought to correspond. Now with regard to the force on the other, or the reacting force, we have observed in a preceding chapter, that there is an active belonging to each point which occupies all the least spaces and fills the interstices lest there should be anywhere a vacuum. This active is present between every one of these elementary particles, and this it is which acts upon the convex surface and perpetually reacts as much as the internal force of the actives acts. The surface is thus equilibrated between two forces. Since therefore there is an acting force directed from the actives toward the concave surface, and an acting force directed from the actives toward the convex surface; since also there is a figure belonging to every force in the surface or to every individual, mechanically conspiring to this and to no other situation; there hence follows a most perfectly exact equilibrium, by means of which the surface is perpetually kept in its own and as it were natural situation, and by help of which it can subsist under any motion; neither can it ever be dissolved, unless the contiguity either in each individual particle, or else between the finites constituting the surface, begins to be wanting.

To the above forces we may add a force on the external part

of the surface, arising from the reciprocal pressure of every particle according to the altitude. This pressure becomes mutual, as soon as the situation of the parts is formed by motion, and, by means of this situation, the vortical figure. In the sequel we shall explain the mechanism of the finites which constitute the surface; we shall shew how they perpetually tend toward the interiors, so that the superficial expanse itself, consisting of finites, is in a certain perpetual reaction against the force of the actives which are fluent within. In this manner then do we see the surface of this first elementary particle in a state of most perfect equilibration; so that no surface can be equilibrated with greater exactness, more particularly as nothing is enclosed with the actives which can possibly modify in any different way their motive force and motion: and much more must this be the case with the actives of the point, or with the finites which trace out the superficies, and in regard to which no mode can as yet be conceived which can superinduce a variation. Hence it follows, that a surface, from the actives enclosed in it, may be called an expanse; also that a surface, equilibrated between two forces, is in its natural situation.

6. *That this surface is most highly yielding and elastic* is evident from this, that there is nothing in the active space within, which is contiguous; for actives cannot present to us anything really contiguous. They are only the images and representations [*simulacra*] of surfaces, which may apparently be in contact with each other, but not really. They are only the phantoms and ideal forms of surfaces. They are only the motive forces of certain extremely minute substantials which represent themselves under the appearance of figure. One of these figures may therefore pass through another wherever it may be, and thus a thousand superficies may flow through and across a single one. In fine there is nothing contiguous presented to us either by these figures or by the actives. Since therefore there is within nothing contiguous which presses, but only images of surfaces or motive forces in effigy and figure, there is consequently nothing within which resists, except the action of each enclosed active, which by its local motion presents the illusion of the superficial form. In fine, since there is nothing within which is contiguous but only what is most perfectly active, which moves and turns every

point with all conceivable actual potency, what other result can take place than that the superficies formed by these or by an active space of such a kind, yields without impediment, is in a moment impelled toward the interiors, is as it were sentient of every external force, or is receptive of every possible impression, is in an instant and in every point able to inflect itself as it were towards its interior space, where there is nothing resisting and contiguous? Its surface in fine becomes most perfectly yielding, nor is there anything more so. If however interiorly there were anything contiguous, and if the surfaces were real and capable of being in mutual contact with each other, then this surface, expanded by what has contiguity, could not be yielding, and convert itself instantaneously toward the interiors, unless also that which had contiguity and was within were equally yielding. Now what is contiguous and within, could not possibly yield, unless every surface or individual constituting what is thus contiguous were equally yielding. But every individual cannot yield, unless there be something else within which is not contiguous. We arrive therefore at this conclusion, *that there can be no yieldance in any surface unless there be something within which is not contiguous, but which nevertheless acts and presses as if it were contiguous.*

Since therefore these actives do not resist as if they were contiguous, but act and push in every manner, it follows that if every point of the surface were pressed inwardly by any external force, it would immediately leave the equilibrating natural situation which it ought to maintain with the enclosed actives, and begin to lose its equilibrium. Inasmuch therefore as the points constituting the external surface cannot subsist together without equilibrium, or the figure, situation, and expanse of which the equilibrium consists, they are impelled by the enclosed actives, or the active space, into their former and natural place; the former and natural figure being thus immediately restored, and becoming after this exercise of force and opposition the same as it was before. The surface therefore is not only most perfectly yielding, but is also most quickly refluent into its former natural state; or what is the same thing, is most highly elastic. For its elasticity consists in this, that it is immediately resilient into the place from which

it was expelled and is the same as it was before. This principle may be illustrated also mechanically; for if the enclosed actives are capable of acting in every possible manner and direction, then they perpetually act upon that point which withdraws itself within the figure, and by reason of which the space is rendered unequal or some part of the equilibrium is destroyed. Hence inasmuch as the actives are always present with their motive force, they cannot cease to act till that point of the surface which was displaced by the external force be again brought back to its situation.

That hence nothing can be more elastic than the surface of this elementary particle. For the surface is, as we have above stated, perfectly equipoised, and consequently nothing antecedently to this can surpass its elasticity. Now if to this be added, as we shall explain in the sequel, a perfect similarity of the finites in the surface, and hence a motion and situation of all throughout the surface perfectly similar, then there can be nothing which can describe or trace out this surface more exactly, and continue it in this state. In consequence therefore of the forces pressing equally on all sides, this surface must always exist in a state perfectly similar to itself, and must almost instantly relapse into the situation from which it had been forced. That its elasticity is nevertheless more perfect in its state of expansion than of compression, will be seen in the sequel.

That its resilience [elater] *is equal to the pressing force, or that it recoils and reacts with the same force with which it is pressed.* This follows in general from the circumstance, that it rebounds to the same place from which it had been forced, and in particular from this circumstance, that the more it is pressed the more it represses and reacts; that its reaction is the less in proportion as the pressure is the less. If the surface be pressed inwardly, the enclosed actives immediately react and restore its figure: if the surface be pressed inwardly still more, the actives still more strongly act or as it were react. The more the surface is forced inwardly, the more numerous are the points of the surface within the active space which can be acted upon. The less it is forced inwardly, the fewer are the points within the active space upon which it can exercise any action. Its force of resilience is therefore always equal to the force of

pressure, or it rebounds with the same force with which it is pressed. We may here add the observation made in a preceding chapter concerning the actives; namely, that a larger number of actives act more strongly than a smaller, and consequently still more strongly if they be reduced into a narrower space, because then more may be conceived as being in an equal space than in a space more expanded. It follows therefore hence also, that the action is as great as the reaction. How it is that under every pressure the surface remains similar to itself, and that no tremors can be conceived as being in this expanse, will be explained in the sequel.

That the sum of the forces before and after conflict is the same, or that in every conflict or pressure the quantity of the forces is preserved. This will be seen from the figure and mechanism of the particle, better than from all the demonstrations which can be adduced. This particle is, as it were, the very figure itself of elasticity; for since the forces of its resilience and elasticity consist in the action of the actives which are within, and since the actives are nothing but motive forces in figure or formed into apparent surfaces, since their sum and quantity remain the same after the conflict or pressure as before, it follows, that the sum and quantity of forces are also the same before as after the conflict. The forces however are increased in proportion as the space is lessened by the pressure or conflict, and these increments of the forces are reciprocally as the spaces.

That the surface when liberated from the compressing force is immediately restored, that is to say, in regard to its expansion and space. That in every degree of compression the figure remains similar will be shewn in the sequel.

7. *That the weight in the surface is imperceptible, for which reason it cannot be said to lose any; and that in the particle thus expanded we cannot conceive of any impetus but what is the smallest possible or none.* Impetus is compounded of the masses and velocities, or is calculated according to the mass and to the degree of its velocity. If the body be perfectly elastic, it will as it were possess no weight, for it thus is rendered more obsequious to the reciprocal force of the elasticity. The finites themselves which constitute the surface of this particle, inas-

much as they are the smallest possible and proceed directly from the smallest substantials, occasion the surface to have the smallest possible breadth; there is also nothing contiguous to exercise repression, but only a certain active space which acts merely and does not resist; the surface also lies between two forces kept in a perfectly equal and natural balance. In such a medium therefore, if we may so call that which is none, there can exist no weight as a cause of resistance. The lighter the medium and the subject of contiguity, the less is the resistance, or the less weight of resistance is perceived. In water the weight of a sailing ship is not perceptible; still less is perceptible the weight of bodies floating in the air, whose particles nevertheless are contiguous to each other. In the present case, as there is nothing contiguous, so there is nothing resisting, but only that which acts, and this not only backward but in all directions. Hence as nothing can be conceived in an active space which can be called resisting, so there can be no weight in the surface or series of finites.

8. From these observations it follows, *that nothing can be conceived either without or within the surface of this particle as resisting, but only as acting*. For by their action actives resist not only at one angle but at all; hence they cannot be said to resist but to act; for resistance implies direction to an end, and a specific quarter from which the resistance comes. Since therefore there is nothing resisting, the medium of which the space consists is as none and as without resistance. In this medium we cannot conceive of any weight, because there is no resistance. By the same continual action by which the actives formed the surface, by the same will they preserve it. It was by their action that they came with the finites into their situation or equilibrium, and by the same action will they preserve it. The cause of existence is the same with that of subsistence; the cause of formation the same with that of preservation. For if the finites went within the active space they would be immediately acted upon, and they could not be sent back in any other direction than toward some point in the surface. Wherever they came back they would come to their like, and consort with them into the same motion. Now since there is nothing to offer resistance, since there is nothing in the active space which can be said to be heavy or to have weight, and yet since there is elas-

ticity, it follows that the resistance consists in the action of the actives not determined to any given angle, but still that it may have a determination as if it were resisting; for since the force acts in every direction, there must be a force acting in that from which the resistance is conceived to come.

9. *That the finites which constitute the surface are connected together in a contiguous series.* They cannot possibly be disposed into any other situation and form than the spiral; extending, for example, from one pole by spires forming a surface, into another, evidently in the same manner as in the finites themselves. From the same cause results the same effect; from the same seal the same impression. In the surface therefore of the elementary particle every finite or individual is connected as to its poles with its proximate finites.

10. *That in this surface the force and effort of all the finites are always the same and perfectly equal.* If the finites are connected with each other, then what happens in one must necessarily happen in the other. By reason of contiguity what happens in one is made perceptible in all. If one is compressed, the same degree of compression is by connexion communicated to all. If by reason of a smaller degree of compression some have the liberty of performing an axillary revolution, so have all the others. Such as is the axillary motion, such are the force and tendency to a local motion. Hence in the surface of this elementary particle the force and effort of all the finites are equal.

11. *That the motion and conversion of one finite in the surface of an elementary particle, is the motion and conversion of another and of all.* The finites or individuals which constitute the surface, cannot here be connected otherwise than they are in the finite itself; they are connected, that is to say, as to their poles and into a spiral figure, from the centre to the surface, and from the surface to the centre, by means of spires; and from one pole to another. There is thus a connexion between them all. If now in this situation, connexion, and contiguity, one be moved about, so are all in contiguity with it. If the axillary motion be diminished in one, by means of the connexion it is diminished also in another, and in all that are in contiguity with it. Thus do all the points in the surface, in consequence of their connexion

with each other, experience the same changes, and this by a natural and mechanical necessity.

12. *That the change of state in one finite causes a change of state in another, throughout the whole surface of the elementary particle.* This follows from the connexion of their first principles, and from the causes alleged in the theory of each finite. In every individual or finite which constitutes the surface of the elementary particle, there is, as we have above stated, an axillary motion, a progressive motion of the parts, and, if there be space for it, a local motion; there are also a spiral figure, poles, and other properties which we have predicated of the first finite in our theory of its formation. These finites are mutually connected, and this at the poles where several of the parts are in contact one with another. If they are connected, then, when one is in a state of compression, all are reduced within narrower bounds, because all are in series and connexion. If they are compressed as to their poles or equators, their axillary motion is retarded or stopped; they cannot have any axillary rotation if they are compressed by their proximates; if they are compressed, the progressive motion of their parts is impeded or stopped; if the axillary motion be diminished or stopped, in the same ratio is diminished or stopped its effort or conatus to a local or second motion, or its power of actuating itself; for it is the axillary motion which is the cause of local motion or of active force. The forementioned finites, therefore, in the surface of the elementary particle, may with facility continue to subsist, because they are for a considerable part destitute of all active force. Thus, in consequence of the connexion between them, the change of state in one causes a change of state in the other.

That change of state in each individual or finite of the surface, proceeds from an external cause and from compression by means of contiguity. All the motions which are in any finite, are mutually dependent on each other; if the axillary motion be diminished, so is the progressive, so also is the effort to local motion; for the axillary motion is the cause of the local: the effect ceases if the cause ceases: the effort or conatus to a local motion is plainly such as is the axillary motion: the axillary cannot be stopped except by contact and compression, that is to

say, by some external cause. If the finites are compressed as to the poles or equators, the conatus, forces, and motions of all are diminished.

13. *That since these finites are in connexion one with the other and constitute the surface, they cannot possibly become actives; but that they generally remain passive and inert.* If there be a mutual contact between them, then by this contact, the same as if by compression, their axillary motion is retarded or stopped; and consequently, together with their axillary motion, their active force and conatus to a local motion. Thus do these finites in the surface of the elementary particle, become more or less passive and inert, according to the closeness of the contact.

14. *That if the finites of the surface were disengaged from their series, or liberated from all connexion with their associate and proximate finites, they could not become actives and betake themselves to a local motion, but must immediately pass into some series of the proximate surface, and join themselves to other finites of the same kind.* They have no space for expatiating and running out into the elementary particles; much less have they any space there except what those circles require which they must naturally describe. There is therefore no space left between the contiguous elementary particles for them to perform even a single gyration: neither have they sufficient room interiorly with the actives of the first finite. Nor is there any number of them by which their force can be rendered stronger. When therefore they are liberated from their connexion with the other finites, they have no power of excursiveness; but must betake themselves into the contexture and series of the proximate surface, and there stay, and with their fellows describe some associate surface.

15. *Nevertheless from one elementary particle there may exist many actives, which, together with the enclosed actives, may occupy a larger space.* This we shall see in our observations upon the active of the second finite.

16. *A small volume of finites may present a large volume of elementary particles.* For the elementary particles are extremely expanded; and inasmuch as their finites constitute only a superficies, a small volume of finites may consequently supply an in-

finite number of such superficies and an immense expanse; just as a small volume of water may supply a large volume of vapor, as is well known from a variety of experiments.

17. *That this elementary particle, consisting of finites and actives, may be compressed into one still smaller and smaller; and again that it may be expanded from a smaller into a larger.* Since the superficies is equilibrated between two forces, it follows that in whatever space it is, it can, as such, maintain its equilibrium. Since also this superficies is most perfectly yielding, it may consequently withdraw itself into a smaller space. The finites themselves are of such a nature that they can move in aggregates; in an entire space as well as in any superficial expanse. They can therefore flow through any surface, as well if they are compressed into a smaller space as if compressed into a larger.

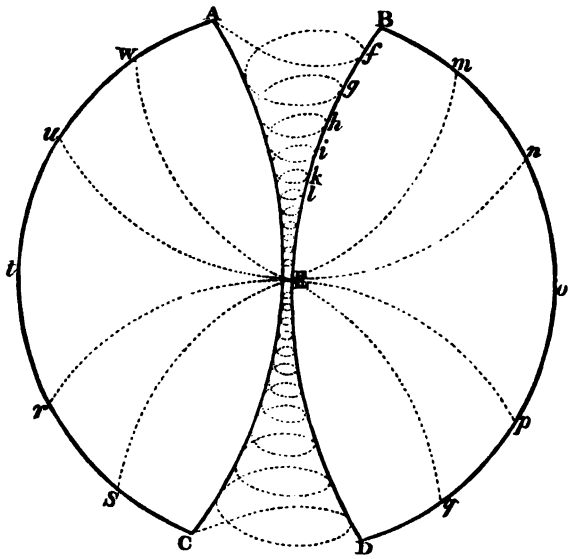
18. *That in every degree of compression the similarity of the surface is most exactly preserved, notwithstanding the surface may be larger or smaller.* An active space can be surrounded only with a perfectly regular figure, so that all the actives or apparent surfaces may so fall upon that cavity as not to have anything angular upon which to exercise their force. Now when all the finites have passed into such figures, that there is nothing anywhere upon which they may impinge as angular, their figure is then the one which is the most perfectly adapted to their space and motion, and this is one cause of the similarity of figure being preserved. The other cause is to be found in the actives of the point, which flow extraneously and act upon the whole external surface with a perfectly simple and almost pure motion; for these actives leave no place empty, but exercise a perfectly pure action upon all, and almost in an instant; nor do they allow of any angle in the surface upon which they can act more than upon any other part; hence also we have an extrinsic cause for which the superficial expanse always keeps perfectly similar. Nor can the finites which compose the surface progress according to any other than their own proper figure; for whatever be that to which one finite tends, into the same tends the other, and all simultaneously or the whole surface. Since then an enclosed active space does not permit itself to be circumscribed by any other than a round figure, nor likewise the actives of the point which perpetually act without,

nor the finites themselves which form the compages and expanse of the surface, therefore nothing can exist to render the figure dissimilar, whether the particle be under a greater or less degree of compression.

19. *That the series of finites flowing through the surface, may flow in a simple, double, or triple order, according to the degree of compression with the adjacent finites.* During the compression, the surface must converge toward the interiors, since it cannot retain its former expansion: for the surface consists of finites cohering in a series and flowing in contiguity; hence in any compression, the expanse becomes less, and the excess must betake itself somewhere, which it can do only in the direction of the interiors, by means of spiral circles; hence, it would seem, the surface may be doubled and tripled; nevertheless, however multiplied, the surface retains its figure, and the finites their situation and progression: for this they are enabled to do from the centre to the circumference, as is the case with the finite itself; and much more from one circumference to another.

20. *That in a state of compression, the elementary particle begins to form certain polar cones towards the centre.* In

Fig. 12.*



* In the original, plate II., fig. 13.

proportion to the degree of compression, it becomes more and more like some finite in which the points or individuals flow from the centre to the circumference, through the poles to the centre, and so on always reciprocally. Since then it more and more resembles the nature of the finites or the figure of motion in the individuals of the finite, the superficies consequently, according to the degrees of progression, betakes itself inwardly, doubles and triples itself, until at length it evidently becomes like some finite, so as to have poles or polar cones. In this case the elementary particle will perhaps not be unlike fig. 12, where the whole space BED*pon* consists of fluent finites, as also the space AECS*rtu*W, whose polar cones are AEB and CED. On this subject however we shall speak in the sequel.

21. *That in the greatest degree of compression the elementary particle evidently changes into some new finite.* Here it is we meet with the limit of compression. According to the mechanism of their motions, the elementary particles cannot change their figure into any other than one like that of the finites, on account of the sameness of the nature and force of all the successives. Of this however we shall speak subsequently.

22. *That the particle thus ceases to be elementary;* for there is no longer any active space round which the superficies flows; there is no superficies which can be more compressed and more expanded. The enclosed actives likewise have gradually banished themselves. Together with the superficies have gradually disappeared all yieldance and elasticity, and consequently everything elementary.

23. *That the enclosed actives have a greater power of acting and reacting upon a compressed, than upon a dilated particle.* If they are reduced to a smaller space and within narrower boundaries, then, according to what we have above stated, they have a stronger power of acting.

24. *That under too great a compression, the enclosed actives begin to lose their force.* For if no more space remains than is equal to the circle or superficies which the active describes and figures, it then has no longer any room for expatiating; and if it be deprived of this, it follows that it is deprived of its force, which consists in its liberty of running out according to its innate force. Moreover by means of complications of series or

surfaces, the sides of the superficies begin to incrassate. Hence also the actives cannot exercise such force upon them as upon a surface consisting of one or two layers or series. The more therefore they are compressed, the less is their force. Moreover,

25. *In the greatest degree of compression the actives evidently disappear; they attach themselves to the finites which occupy the surface, and plainly cease to be actives.*

26. *It also follows that the elementary particles cannot be destroyed by any degree of compression, but that they ultimately become a new finite.* The series of finites constituting the surface approximates more and more to the figure which they are naturally capable of having, and representing by their inherent motion or force; and this figure is similar to that of every finite.

27. *That in their greatest degree of expansion they may be destroyed and dissolved.* By their expansion is ultimately dissolved the connexion which one finite has with another; and consequently when the connexion is dissolved, the expanse can no longer be considered as contiguous, but as a rarified and dispersed number of finites, which, liberated from contiguity, begin to have a more rapid axillary motion and to become actives; nor can they observe the same course, or have the same periphery and superficies, as when expanded by connexion. By too great an expansion therefore they may ultimately perish.

28. *That they may be dissolved also by actives acting upon them from without.* For if there be an active space without, and if an elementary particle approach and enter it, it might be possible for it to be dissolved by the force of the surrounding actives; but this will not be the case, if it remain in volume and in contiguity with the other elementary particles.

29. *That these finites may become actives.* For when set at liberty, they have the force which the finites have, or the first substantials of which they are compounded. They may therefore become actives and occupy space, in which they may in like manner exercise their active force. Of this however we shall speak in the sequel.

30. *Or that else, when at liberty, they may pass into the superficies of others which are similar, and there continue their motion.* For they cannot perform their active or local motion

between their elementary particles, inasmuch as the interstices are too small to allow them to perform their entire gyration; hence they run with a simple force upon the convex limits of the elementary particles; and by an illapse into them, are received within their series and superficial expanse as their companions. In this manner it is they become passive and inert.

31. *That in this elementary particle may be presented all possible degrees or species of elasticity; but according to the degree of compression.* If these elementary particles are compressed, their superficies is immediately doubled and multiplied, and made capable of exercising a stronger resistance. The actives also, confined within a smaller space, receive a stronger power of acting; therefore the elasticity which is greatest in the greatest expansion of the particle, is gradually rendered more resisting and stubborn. *Hence it follows that they possess a greater elasticity when they are expanded, and a less when they are compressed. In the highest degree of expansion their surface is the most highly yielding, becoming gradually the less yielding the more it is compressed; till finally in the highest degree of compression it becomes hard and non-elastic, and at the same time ceases to be elementary.* For when the elasticity ceases, then also that ceases which is elementary, or which renders the particle elementary; or in other words, which enables it to move in particles, to apply itself to every locality, to form a vortex and exercise an infinite number of other functions, which, if the elasticity of the parts be maintained, result from their acting in a volume. For the actives have disappeared, so that now nothing remains active; and yet without an active nothing elementary can be conceived.

32. *That one elementary particle touches and presses upon another; and by means of this contact forms a contiguity of one particle with another.* Inasmuch as every particle possesses a superficies and occupies its own proper space, it may likewise be in contact with another particle. Without contact nothing can be made contiguous. It is from contact that contiguity exists; and, together with it, all elementary nature, which has its existence and consistence in contiguity. The greatest contact, or that of the greatest number of points, appears, according to the mechanism of the figure, to be around the poles: at the

æquators, however, where the particles are roundest, the contact is only in the smallest possible point.

33. *That these elementary particles cannot be in contact, except in a manner accordant with the motion of their surface and their figure.* Inasmuch as their elementary principle consists in a capability of being moved in particles and also in volumes, so that the motion of the volume is as that of the particles and the motion of the particles as that of the volume; inasmuch also as by reason of the yieldance and elasticity of every surface, they can be in every motion and apply themselves to it, and in like manner touch each other only in one point at the equators; it follows that they cannot be put in motion one among another except in a manner conformable to the motion of their surface and their figure; all other motion being contrary to them, and either stopping, disturbing, or impeding their great mobility, and consequently introducing irregularity into their general motion. This circumstance however being purely mechanical, and following mechanically from the motion of the parts, there is no need of further observation upon it.

34. *That these elementary particles cannot touch each other except when in a parallel situation. That the poles of all are in a parallel situation or line, as also all the larger and lesser circles; and that they are kept in this parallelism by the mechanism of their figures, and their contact at the poles.* Their situation is of a spiral form, and similar to the situation of the parts in every finite; being as it were a kind of spiral contortion. Since therefore in the surfaces of all the elementary particles, the situation is similar and of the kind we have mentioned, it follows by mechanical necessity, that their mutual situation must accord with the current of these particles as they run into a spiral, and that naturally they are simultaneously moved in accordance with this general fluxion of all. Thus it is they connect their sides, and join them in contact, and are carried consentaneously into every larger motion. In a contrary situation there arises a renitence, a counteraction between the particles in contact, and a disagreement, preventing the motion of the parts in each from being free, and producing a disturbance in the equilibrium. The very mechanism of the situation and figure therefore occasions the particles to move one among

another with most facility, if the second motion of one surface be the second motion of the other; that is to say, if their situation be according to the situation of the parts in the surface and according to their figure; as when helices are in motion one among the other; in which case they must attach themselves to each other according to their motion and figure. It is at the poles principally that the parts are in contact; at the equators the contact is only in one and the smallest point. Consequently nothing can so mechanically direct the situation of every particle in motion, as a contact between several parts, and which is to be found only at the poles. Hence it follows that all their larger and lesser circles, as also all their poles, are exactly parallel with each other.

35. *That nevertheless they may be easily displaced from their situation; but that they immediately return to it as their natural one.* Since their conjunction is only in a few points, and since the particles themselves are most perfectly yielding, they are consequently not so firmly connected with each other but that they may be easily dislodged from their situation by any external force. Inasmuch however as their mechanical situation is in accordance with their axes, and consequently is their natural one, they spontaneously relapse into it after displacement.

36. *That several of these particles, or a volume, when put into motion, cannot be circumfluent otherwise than accordantly with the parallelism or situation of each.* This is a consequence of what has just been said. For if a volume of particles be circumfluent, all of which are by a mechanical and consequently natural force kept in the same situation, the whole volume cannot be circumfluent in any other manner than in such as to preserve the same situation which the particles severally possess. For each respective particle contains the cause of the whole; the whole follows the direction and determination of each part. The motion of the volume therefore can be no other than the motion of the parts; that is to say, the several axes are in the motion of the volume, and are the axes of its motion.

37. *That from the motion of the volume of the particles exists their vortical motion. And that no other particles can be better adapted to a vortical motion than these, by reason of their figure and elasticity.* Not only are they kept mechanically in their

situation, but also conformably to it, one is moved when the other is. In consequence of this connexion, though on so minute a scale, the one brings the other into its own motion. All therefore possessing a similar force, figure, and mechanism, are easily brought into the same motion; and inasmuch as this motion is circular, it is vortical. Their extreme elasticity is also another cause of their perfect aptitude and proneness to a general motion. By their elasticity the particles are suited to move in every place and under every degree of compression: that is to say, they can move under any force, pressure, and weight; so that they can continue similar in the space and figure of their motion; and in case any inequality be impressed upon them, it becomes distributed equally through all. Since therefore by reason of their extreme elasticity they may always continue similar in figure, they are consequently all most highly adapted to one and the same general motion; and, as we shall demonstrate in the sequel, they all spontaneously flow into this motion, if only a state of action be supposed. Since therefore the superficial figure of all is most exactly alike, as also the motion which forms this figure; since all have the highest possible yieldance and elasticity, and exercise the same common effort, it follows not only that all have the greatest aptitude and tendency to a general or vortical motion but also to a continuance in it, as it were, without any renitency.

38. *That upon the exercise of the slightest force they naturally flow into a vortical motion.* For since they are not only most highly prone but also most highly suited to a common or vortical motion; since the figure of each particle respectively conspires to this and to no other motion; since also all tend to a local motion, as will subsequently be shewn; it follows that merely in virtue of the origin of their motion, whatever that origin may be, they tend to no other than a vortical motion: just as the least sound, the least commencement of motion in the air, puts a volume of its parts into a motion undulating from the centre to the circumferences and on every side circularly; as we see also in water and in every element whose phenomena come within the cognizance of the senses. This tendency is more particularly observable in the present case; in which one particle, as it were, assists another in the performance of the same gyre

with its own; a gyre into which, in consequence of their elasticity, all most readily and similarly flow; so that upon the slightest origination of motion they flow spontaneously into a vortex. If their motion be vortical, there must be some centre of motion from which it begins the distances from which are its circumferences.

39. *That there can be no other vortical motion among the particles than such as is accordant with the figure of each particle, and constantly refers itself to some axis of motion or gyration. Likewise that the vortical motion forms to itself a polar axis.* Since all the particles have their poles and axes, according to which they form their situations parallel to each other, they also so dispose their general motion as that this also shall have a like axis to which to refer itself. *The circles of vortical motion among the elementary particles which are farther from the centre, more and more inflect themselves till they come into a right line with the axis.* For if these figures and surfaces, which are in a motion perfectly circular, were devoid of an axis, they would then run into circular peripheries and superficies; since in this case there would be nothing dissimilar to drive them out of this course into any other. But if these figures and superficies be axillary, and if their situation be parallel to their axes, they will then recede from these peripheries, and inflect themselves in a direction parallel to their axes; a result which follows from the mechanism of the parts.

Until the vortical motion terminates in a right line, and so vanishes in a direction parallel with the axes of the particles. If the circles, in the course of their progressive motion, gradually inflect themselves towards the axes which lie parallel to each other, the motion passes out of an oblique into a rectilinear direction, or into a situation the same with that of the axes.

That a vortical motion arises from the exercise of a motive force in a given centre; and when thus begun from a centre, the greatest motion is nearest to the centre, and the least at the outermost peripheries. Wherever the force of motion begins, it sends the particles next to it into a gyre. At the first commencement these particles always resist the acting force before they become habituated to the motion, and before they urge the entire volume into the same gyration; for these particles are contiguous,

and one cannot move without another; if therefore one be put in motion, so will another, so will also the adjacent particles to some considerable distance; and these also, before they can follow the others into the same motion, must first be urged by their proximate particles; but when once put into motion they spontaneously follow it. Thus the atmosphere, under any percussion at first resists, but when accustomed to the percussive force, its proximate parts pass in volume into the same motion; for by reason of the contiguity of the parts the motion extends itself to a gradually increasing distance from the centre.

That the polar axis of the particles is the same with the polar axis of the zodiac, and their equators the same with the zodiac of the solar vortex. Inasmuch as this first element is the most universal, passing through all the vortices, and being a contiguous medium between the eye and the sun as well as all the stars of the heavens, it follows also that it is the most universal element of our own solar vortex. And since we see in the middle of this vortex a sun, which is most perfectly active and always acting upon the volume of these particles, we cannot hence come to any other conclusion, than that it is this element more especially which is put into a vortical motion. From the orbits of the planets we learn, that its motion observes principally a greater circle, or the zodiac; which, according to the principles we have laid down, is the same with the larger circle or equator of each particle, while the poles of these particles are the same with those of the zodiac.

40. *That superficial matter or finites, flowing through a surface, may, near the poles, pass into the surface of the neighboring particle.* The greatest contact is as we have said at the poles; because these are parallel one to the other, and the particles are as it were conjoined to each other by their poles. Consequently one finite may, at the poles, pass into the surface of the other. In every particle the polar circles have a certain degree of latitude; hence they are in several points at the poles in contact with each other. The very reciprocation of the motion of the finites, also, through the superficies, exists at the polar circles; by means therefore of their vicinity there may be effected a communication of the surface of one with the surface

of another, and consequently a transition of the matter of one into the surface of the other.

41. *That by this translation of the finites and superficial matter from one surface to another, the surfaces of the particles may be diminished or enlarged; that is to say, they may be made smaller or larger, and thus may be brought into equilibrium, in regard to space and weight, with their adjacent and associate particles.* Innumerable may be the contingent causes for which one elementary particle may not be similar to another. For if the space occupied interiorly by the actives be larger, there results a larger surface and a larger particle. If a larger quantity of finites surround either the same or a similar space, it follows that the surface will be in like manner larger or smaller. If an immense space filled with actives press a volume of finites into a narrow compass, and gradually form them into these elementary surfaces, there may be innumerable causes for which one element may be larger than another. In fine the elementary particles may at the commencement be unequal, although we are to conceive that, so far as contingent causes allow, nature will always have preserved an equality with herself. Nevertheless, if elementary particles, unequal to each other, come into existence, still they can be reduced into equality with each other by means of the transition of the matter of one surface into that of another. For when by their vortical motion all the particles are brought into a regular situation, if at any distance from the centre and under any degree of compression, they do not with equal facility flow into the same motion and figure of motion (for they ought all to be equal, since without equality of parts there is no equality of volume), then, by means of the mechanism exemplified by the influx of one through the poles into the surface of the other, they may be brought into equality one with the other, and may all occupy a like space, and have a like quantity of matter or number of finites in the surface. Were I to go farther into the subject of this natural equation, I should open an immense field for contemplation; and one in which I should have to present to my readers remarks which at first might not appear to harmonize with the ideas of some of my readers.

42. *That the enclosed actives follow their particle as if in their own natural location, and that they are not sensible of the local motion of their particle. The case is the same with the finites which occupy the surface, if there be a local motion of the volume.* We cannot conceive of place except in what has contiguity; for place has relation to parts in contiguity; neither is there any relation of place where there is nothing contiguous. The apparent surfaces of the actives give rise to no contiguity between them; for no one surface touches another; nor does one active as to its figure hinder another; neither do the parts keep together in real surfaces; that is to say, they can have no relation of parts in contiguity. Hence one active cannot be said to be distant from another, unless the distance be conceived as imaginary, and a boundary be presumed in the apparent surface, which, in consequence of the change of place and the varying determination of the active, cannot be given. Now since each and every active, with all the imagery of its surface, subtends no certain place, so neither do all collectively which occupy the entire space. Their place and boundary of gyration is where the surface of the particle is, and collectively they constitute but one. For the same reason neither can the surface or whole elementary particle, in its general motion or volume, be said to experience any change of place. Because there is no interchange of place between one particle and another.

43. *That the cause of their compression arises from the action of one upon the other, by means of a motion proceeding from some large space occupied by the actives.* For if there be a large active space, there is immediately an action, at the boundaries next to the space, upon the circumfluent elementary particles, which in these outermost bounds are agitated by the actives, each according to its nature; consequently the motion between the elementary particles is greatest at the boundaries of the active space: this motion is derived from these into the particles next in contact, and consequently spreads around in a vortical form. The greatest motion therefore is at the first beginning of the motion. In all other parts, the motion is derived from the particles here situated to the next, from these to the next, and so on in succession.

44. *That a compression of the particles may arise also from*

their mutual incumbency. When the elementary particles are so reduced by motion into a regular situation, that the volume acquires a situation accordant with the figure of each of its particles, there arises hence another pressure which is the mutual pressure of the particles; the pressure of one upon a second; of a second upon a third; and so on throughout all the radii and circles of the volume. For if from any cause, such as that of motion, the volume be brought into a regular situation, it will by the same cause be retained in it; for when the cause ceases, there is a cessation also of the effect. All the elementary parts, therefore, are put into this motion by the large active space, and by themselves and their own effort to a local motion: from these the motion is derived, at various distances, into the contiguous particles. One therefore is urged into this motion by another; by this motion one becomes pressed by its proximate; and consequently the most remote by the first through the intermediates. By the operation of the same cause, they are perpetually retained in the same situation or figure of motion. Hence there is a perpetual action and pressure of one upon the other; and this pressure is denominated an incumbency according to the altitude. This pressure cannot exist except in a vortex, or volume in motion, and which is thus brought into a regular situation.

45. *That there is in the volume the same elasticity and ratio of elasticity as in each particle.* Since the particles throughout the volume are contiguous, it follows that in a volume of this kind not only does elasticity exist, but also the same ratio of elasticity which is in each particle. For one particle cannot be sensible of anything of which the other is not. The sensation is derived from one to the other in the same manner as the motion. For the cause of the motion is the same with that of the pressure; as we have above stated.

46. *That these particles press upon each other according to their altitude in their vortex.* For since pressure arises from the motion of the particles, it follows that where there is the greatest motion of the parts there also is the greatest pressure. It is from degrees of motion that there arise degrees of pressure. For it is a law both of mechanics and of nature, that the cause of action is local motion; or that active force consists in local

motion. If the motion be greater at the centre than at the circumferences, there is consequently a greater pressure at the centre than at the circumferences, a pressure which decreases in proportion to the distance from the centre; therefore both the degrees of motion and the degrees of pressure among the particles are to be reckoned according to their altitude.

47. *That these particles also exercise a pressure altitudinally according to the base or area subtending the altitude.* For if the pressure be according to the altitude, the pressure upon a greater number of parts is greater than upon a less. Upon all the parts of one body the pressure is equal; if there is a greater number of parts, the pressure is upon a greater number; consequently the pressure is increased and multiplied according to the number and quantity of the parts which oppose; that is to say, according to the base or area subtending the altitude.

48. *That they press equally upward and downward, according to the altitude.* In all motion and action, the reaction is equal to the action. Bodies which are moved resist with a force equal to that by which they are impelled and urged into motion. And since the vortical motion is in the direction of the circles and the radius, and is also intermediate between the two, it follows that the pressure is the same with the action according to the altitude; and inasmuch as the action is the same with the reaction, and the repressure of the particles in the elements the same as the pressure, it follows that the pressure and repressure in the element is equal, as is also the effect produced upon all the opposing particles at the same altitude.

49. *That these elementary particles do not press so obliquely as aërial particles.* There is another mode of pressure which is according to the axis of the volume formed by the axes of every individual particle; as will be seen in the theory of the magnet. For there is no contact between parts configurated as those are which we find in the highest periphery or in the equator; but the contact is principally in the polar circles; hence there arises one kind of motion and pressure which is according to the axes, and another which is according to the equators. All the motion between the axis and the equator is oblique; and the particles must participate in this obliquity, both in regard to the motion or pressure which is at the equators and that which is at the

axes; and this motion or pressure cannot be the same with the motion or direct pressure according to the equators of the particles or their altitude in the vortex. Of this however we shall speak in our theory of the magnet.

That the altitude of the particles is only according to the plane of the equator of each particle, or according to the plane of the zodiac of the solar vortex. The equators of all the particles form our zodiac; the poles of the particles are our zodiacal poles; hence their altitude is according to their mutual contact, and consequently according to their distances in the plane of the zodiac.

50. *That this element is the most subtile, the first and most universal, of our mundane system and of the universe in general.* Inasmuch as this element is the first, it follows also that it consists of the smallest elementary parts. That it is the most universal, may be concluded *à priori*; because it is the origin of all the subsequent elements; because also it consists of the smallest constituent parts, can occupy the smallest spaces, and be present where no other element can; hence it may without doubt be concluded, that it is also the most universal. We may come to the same conclusion also *à posteriori*; for in the starry heavens we see with the eyes all the stars as it were present to us, yet this presence cannot be effected without contiguity. Consequently from reason instructed by the senses we learn, that there is nothing more universal than this element. From reason it follows, *that in every system, both the greatest and least spaces are occupied by this element; and that this element is of all others the most perfectly contiguous.* As all the essentials of contiguity are latent in every particle; as all the particles may be mutually applied one to the other, and in consequence of their figure and situation may all conspire to one consentaneous motion; as in virtue of their extreme elasticity they may accommodate themselves to every motion; so also in virtue of their simplicity they are the first and most subtile element, and consequently admit of the fewest possible modes and variations. Thus from reason, instructed by the phenomena presented to the senses, we learn, that it is *in virtue of this universal element that all things in the starry system appear as it were present. Whenever they do not appear so, it is only in*

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47. *That these particles also exercise a pressure altitudinally according to the base or area subtending the altitude.* For if the pressure be according to the altitude, the pressure upon a greater number of parts is greater than upon a less. Upon all the parts of one body the pressure is equal; if there is a greater number of parts, the pressure is upon a greater number; consequently the pressure is increased and multiplied according to the number and quantity of the parts which oppose; that is to say, according to the base or area subtending the altitude.

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50. *That this element is the most subtile, the first and most universal, of our mundane system and of the universe in general.* Inasmuch as this element is the first, it follows also that it consists of the smallest elementary parts. That it is the most universal, may be concluded *à priori*; because it is the origin of all the subsequent elements; because also it consists of the smallest constituent parts, can occupy the smallest spaces, and be present where no other element can; hence it may without doubt be concluded, that it is also the most universal. We may come to the same conclusion also *à posteriori*; for in the starry heavens we see with the eyes all the stars as it were present to us, yet this presence cannot be effected without contiguity. Consequently from reason instructed by the senses we learn, that there is nothing more universal than this element. From reason it follows, *that in every system, both the greatest and least spaces are occupied by this element; and that this element is of all others the most perfectly contiguous.* As all the essentials of contiguity are latent in every particle; as all the particles may be mutually applied one to the other, and in consequence of their figure and situation may all conspire to one consentaneous motion; as in virtue of their extreme elasticity they may accommodate themselves to every motion; so also in virtue of their simplicity they are the first and most subtile element, and consequently admit of the fewest possible modes and variations. Thus from reason, instructed by the phenomena presented to the senses, we learn, that it is *in virtue of this universal element that all things in the starry system appear as it were present. Whenever they do not appear so, it is only in*

consequence of our being accustomed to measure distances by comparing the angles made by distant objects with those immediately proximate to the eye. It is in virtue therefore of this element, that we can contemplate the remotest stars, as also the planets by their reflected light.

51. *That in this elementary particle is latent all that had preëxisted, such as the point, the first finite, the second finite, and the active of the first finite.* We have thus in a microcosm the whole of our macrocosm; we have the entire world, so far as it has yet developed itself, in each particle, in which therefore we may contemplate a compendium of the whole mundane system. For from a point produced from the infinite arose the first substantial; from the first substantial, its active as also its passive, that is to say, the active of the first finite and then the other finite. Thus does this first elementary particle, consisting of the active of the first finite and also the second finite, comprise within itself all that as yet is active and passive in the world. Thus have we the world concentrated in a single particle. I entreat the indulgent reader to pardon me for venturing to speak so positively of the elements and entities of the *natura prima*, which are so unknown and occult; and as if they were objects well known and familiar to the senses. It would indeed be rash in me so confidently to lead him through such an unexplored region, a region of so many clouds and shadows, were I not aiming, through the medium of the principles propounded, to arrive at an element in which we are enabled to make experiments, and which, by help of these and geometry, may be subjected to the most accurate examination. When we have arrived at this station, if it shall appear that there is a geometrical harmony between the experiments and our principles, if a connexion be pointed out between the first ens or simple and the fore-mentioned element, I then flatter myself that I shall have won the assent of my reader; more particularly as, in the present age, there is no other way left for us to open the secrets of nature.

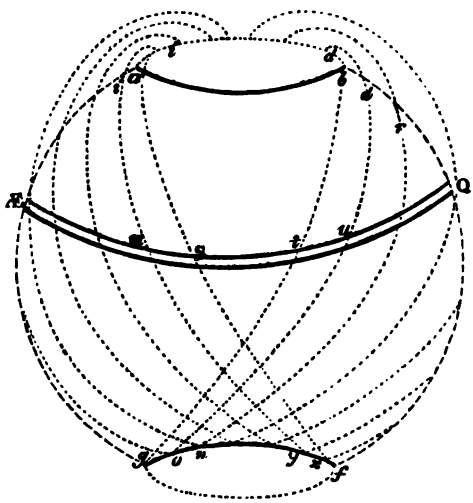
A GEOMETRICAL TREATISE ON THE FIGURE, AND A MECHANICAL TREATISE ON THE SITUATION AND MOTION, OF THE PARTS AND OF THE COMPOUND; BOTH IN FINITES, ACTIVES, AND ELEMENTARIES.

We are now at liberty, for the first time, to explain the geometry and mechanism, or the figure, situation, and motion of the entities or particles; inasmuch as we have now spoken of finites, actives, and elementaries. Between all these prevail the greatest similarity both in situation and motion; because it is one and the same force which produces and creates figure, situation, and motion, both in finites, actives, and elementaries. They may therefore, in consequence of their agreement in these respects, be geometrically and mechanically described all together. With regard to finites, we observe;

1. *That the individual parts in a finite or compound are similar to each other, both in regard to figure, situation, and motion; that the individual parts of these again are also similar, and so on up to the first point in which lies the primitive force and first cause of finiting the sequents.* It is in similitude that consist the sequence and connexion of things in regard to existence and subsistence. In the first motion and figure there is no angularity or inequality; nothing which can by derivation be rendered geometrically or mechanically dissimilar. It is an ens without modes, being most simple and most perfect. Derivatives do not inherit any dissimilitude from this ens. Consequently similitude is derived into its compounds, and again into the compounds of these successively.

2. That the situation of these similar entities is obtained by motion, and that the figure both of the motion and situation is spiral; that hence arises a conatus to a similar motion and figure; and afterwards, again, a similar conatus, as we have above shewn upon principles both of reason and geometry. Poles also and polar cones are necessarily formed by this spiral figure. With regard however to these spires or spiral circles, I observe, that the spires nearest the centre have a greater curvature, and those farther off a less, both in the polar cones and in the surfaces; also that in the polar cones the kind

[*rationem*] of spire is different from what it is in the surfaces, whether it be nearer to or more remote from the centre. A finite which is an aggregate or congeries of parts reduced by motion to a certain situation, does not consist of one surface, layer, and row extending from the centre to the outermost surface, but it consists of several; for it is a corpuscle whose individual parts are similar one to the other; it has a convex figure, but at its two opposite ends it has its poles gradually widening from the centre, and hollowed out into the form of two cones. Thus we see, from the geometry of the figure and mechanism of the situation, that both in the polar cones and at the surfaces, the spires at the centre have a greater curvature than the spires at the surface. With regard to the spires of the poles the reader is referred to Fig. 12 (p. 155), where the polar cones are AEB and CED, the spires near the centre *l*, *k*, *i*, have a greater curvature than the spires *h*, *g*, *f*, above; a curvature which becomes less and less in proportion to the distance from the centre. The same is the case in the surfaces extending from one pole to the other, till we come to the outermost surface in which the spires are similar to those which are represented in the following figure, and which run from *g* to *b* and so on; in the



interior parts however they pass through several gyrations, or circles running round the surface, before they come to the other pole. The cause of this fluxion is mechanical. Let the corpuscles in this figure be conjoined at their poles, and thus connected together into a line or chain, let the chain thus formed be so gyrated as to cross from one pole in the figure to another and to produce a surface; in this case we cannot turn it round without forming spires, running over the surface from one pole to the opposite. In this manner will similar individual parts inflect themselves, when connected as to their poles; they will first pass into spires similar to the polar before they can be brought over the surface to the opposite pole; and thus by a continual relation to their poles, they will advance into a new surface and onward to the ultimate or outermost, where, both in the polar cones and in the surfaces, the spires are of less curvature; the situation of the parts relatively to their figure and centre being always preserved.

3. *That a small cavity is left in the middle, which on one side extends farther from the centre than on the other.* If we have a spiral as in Fig. 1 (p. 106), where the centre is in *a* and the flexure of the spire in *b, h, i*; it follows that on one side, the distance from the centre is greater than on the other: a property which is essential to every spiral. If the situation of the parts be spiral, then whatever be the manner in which the spires are formed, the distance from the centre is unequal, being greater on one side than on the other. The same is the case in the present instance. If we would turn round the forementioned chain which consists of corpuscles of like figure, linked together into the form of a spire, always preserving the connexion and situation of the parts relatively to the centre, we shall find there is no mode of doing so without making the distance on one side of the centre greater than on the other. From the same mechanism it follows, that the plane of the ecliptic cuts all the superficial spirals midway from their centre; so that there is as great a length of spiral on one side reaching to the centre or pole, as there is on the other.

4. *That the centre of gravity is situated without the middle and in the plane of the ecliptic.* If the figure be spiral its centre cannot be in the same place in which it would be if it were merely circular; if the cavity in the middle be wider on one

side than on the other, the centre of gravity cannot be in the middle. In like manner in no other plane but that of the ecliptic can all the spiral arcs be cut in the middle: this is the plane, consequently, to which all the spires have on every side consentaneously a relation.

5. Before passing from the figure of this finite or its geometry to its motion or mechanism, we will add that in every finite, active, and elementary, there are larger and lesser circles, an equator, ecliptic and meridians, because there are poles as in Fig. 7 (p. 135), where ÆQ is the equator, which is in the middle between the poles and parallel to the polar circles *ab* and *gx*. The meridians run perpendicularly from it to the poles. The latitudinal circles are the same with the spires in the surface (Fig. 7. p. 135), such as *bg*, *a*F, and the others. The bisection of these will give the ecliptic, whose poles are consequently in the polar circle.

6. *That there is an axillary motion of the whole corpuscle; which is greatest when the corpuscle is most at freedom, less in a state of compression, and none in the highest degree of compression;* as is evident from what has been previously said. In like manner, *there is a progressive motion of the parts* in consequentia *or according to the plane of the ecliptic: the progressive motion is also greatest in the greatest state of freedom, and least or none in a state of compression. Also, from an axillary arises a local motion; this local motion is determined by the centre of gravity, and is directed by the progressive motion into the figure of a surface.*

7. With regard to actives, it follows from their mechanism, *that the local motion by which the surface is described is spiral; that in this apparent surface there are poles; that it has larger and lesser circles, like finites; and hence that in respect to figure, finites and actives are similar to each other.* As in figure, p. 171, where *bg*, *do*, *iy*, *ax*, are perpetual spirals, which in their course form the nodes *t*, *u*, S, *m*, with the equator, and which are also equal to each other. Moreover, if the fluxion of the active be spiral, there must be poles. Without poles no surface can be formed by a spiral motion. The largeness of the circles or polar cones depends upon the geometry of the spires. The

other circles necessarily and geometrically follow the spiral figure itself; such as the equators, ecliptic, and meridians, all which are concomitants of the spiral fluxion.

8. *That the elementary particles are, in regard to their figure, similar to the finites and actives;* because they consist of finites or individuals of the same kind, character, and figure. Their similarity consists in this, that the finites constituting the surface of the elementary particle are disposed into a spiral situation and figure, and are consequently endowed with poles or polar cones; as also that by their surface are represented an equator, ecliptic, meridians, and all the other circles. Also, that in the cones there is another kind of spire than that in the surface; just as in finites and actives.

That in elementary particles the centre of gravity is in the surface; particularly during a state of compression when the surface is, as it were, convoluted into several plicatures. For if the figure be spiral and similar to the figure of the situation of the parts in the finites, if several and multiplied surfaces be formed by compression, then, according to the geometry of the spiral, the centre cannot be in the middle as it would be if the figure were circular, but must be at a distance from the middle. And since, in the present case, there is no distance from the middle except in the surface, (for in an active space there is no middle, because no kind of distance or weight,) hence there is immediately derived from the centre to the surface all that is said to have gravity. The centre of gravity therefore is in the surface, particularly in a surface composed of several plicatures and ranks; it is also in the plane of its ecliptic.

In every elementary particle consequently there is an axillary motion. For there are the same individuals in it as in a finite having an axillary motion; it has the same situation; the same force, if it be in a state of liberty; and consequently, from the force common to all, there arises a common motion, conformable to the equator, or round the axis. From a parity of reason and of causes it follows, that *in every elementary particle there is a progressive motion, as also a local; or a force and tendency to a local motion.*

That the axillary, progressive, and local motion of the ele-

mentary particle is the same in its state of expansion as in its state of compression. The elementary particle, when compressed, undergoes this compression not as to the individuals constituting the surface, but only as to the active space and the multiplication of the surfaces. For interiorly in the space, there is nothing that resists but only that which acts; thus the active space cannot compress the surface. Therefore the elementary particles are almost in the same state of liberty, when compressed as when dilated; and consequently the individual parts in the surface are almost equally mobile, and possessing the same force in a state of expansion as in a state of compression.

That the elementary particles, in a state of expansion, tend into a larger circle; and, in a state of compression, into a smaller. The more an elementary particle is compressed, the more its surface is multiplied, and the greater number of spiral circles and surfaces are there with which the active space is surrounded; consequently the more does the centre of gravity recede toward the interiors. Inasmuch as the centre of gravity directs the local motion, the nearer it is to the centre of the particle, the smaller is the circle into which it directs its course, but the larger the circle, if the elementary particle be surrounded with fewer plicatures and surfaces. The consequence of this is, that the elementary particles, upon the slightest action, tend to flow, in their volume or spontaneously, into a circle. For if every particle tend to some motion, then do they all, both as to their volumes and as to each separate particle, tend to this motion; if only a slight cause of motion or of action in their volume be given. Thus are they as prone and as apt as possible to a vortical motion; a motion which, for the same reason, they perpetually continue. For if the particles nearer to the large active space are in a state of greater compression than the particles which are farther off, then those which are nearer to the space tend to a smaller gyre and circle, and those which are farther off into a larger; as is evident from the rule already propounded.

That finites constituting the surface of the elementary particle cannot be connected and conjoined in any other way than at the poles; and in a situation perfectly similar as to the centre of gravity of each. For there is a perpetual action exercised upon them by the enclosed actives, or the actives of their own space.

These actives exercise their least action upon the convex side of the finites, and their greatest upon the poles, if the poles be turned toward them; consequently, with regard to the actives, which are within and those which are without, they can form an equilibrium in no other situation than in the one in which the part least subject to action is opposed to the active space; this part is the circular, and the lightest, in which there is no gravitating centre. Therefore by the continual action of the active space they cannot occupy any other situation than such as is suited to the action of this space; that is to say, the finites must turn to this space their convex side, and consequently become mutually connected at their poles. Their centres of gravity are in like manner kept in a similar and conformable situation.

9. *That there is a mechanical, geometrical, and physical necessity both for the situation and motion of the parts and their compounds.* All entities which are in motion receive their determination and direction according to their force and figure; and by motion are determined and directed to their equilibrium. And if they are put into motion by any force, it must be in a manner suited to their figure and force; that is to say, in accordance with their geometry and mechanism. Into this situation, motion, and figure, and into no other, can they come, upon the occasion of any contingent cause or physical necessity. Although, however, causes may be necessarily contingent, yet they do not for this reason cease to be contingent. Nor in case there were offered any sufficient reason for the things which are contingent in the world, or in case the connexion of things were assigned in regard to their existence and subsistence, as also the connexion of their modes, would any absolute necessity be concluded; but only a physical necessity, from which subsequently flows a geometrical and mechanical necessity. With regard therefore to finites, actives, and elementaries, it may be predicated, that, in a geometrical and mechanical point of view, they can be formed in such only and in no other manner: necessity it is which moves and configurates: necessity it is which moves and configurates in that particular manner; a necessity without which there could exist nothing regularly or naturally; nor could the world subsist or have come into being.

CHAPTER VII.

THE ACTIVES OF THE SECOND AND THIRD FINITE.

1. *THE primitive force in the point, such as we explained it, cannot be otherwise than derivative; and by its derivation must, when the occasion is presented, raise itself higher and higher; and by its multiplication into itself produce other similitudes to itself;* that is to say, the primitive force in the point, which arises from the continual spiral motion from the centre to the circumference and reciprocally, cannot but be derived successively by multiplication, into others; so that from the point there must exist others similar to the point; and hence by its multiplication this point must ascend to higher and higher powers; so that from these points finites derive their existence by an order of succession or one after another, as also actives one after another; all having a perfectly similar nature, and differing only in regard to dimension, or in regard to degrees of greater and less. This follows not only from the circumstance that the primitive force in the point is most highly active and motory, most regularly, similarly, and perfectly active; but it follows geometrically also from the circumstance, that of all others the spiral figure is the most perfectly mechanical, without angularity, without inequality, and devoid of every mode which can produce out of it inequality. Now since a figure of this kind is presented to us in the point; and since it exists by motion; it follows that all the force which can ever exist in such a motion and figure of motion, will derive and propagate itself in a most perfect and similar manner. For there can be nothing in the figure itself to beget any dissimilitude or inequality; nor is there

anything in it to diminish the force. By means of this primitive force, therefore, one finite exists from another in successive order; as in like manner do the actives, which are all of a nature similar one to the other, and indeed of the same nature with the point. *Everything mobile, therefore, both in the several mundane systems and in the whole universe, exists and perpetually subsists in the point.*

We have therefore this force derived into the first substantial; and from the first substantial into the second; a force which is employed not only in finiting itself, but likewise in actuating itself as often as occasion is given.

2. *All the finites which arise from any point have a similar power both of finiting and of actuating themselves.* Since the primitive force is derived into the sequents, and is similar in the sequents to that from which the sequents derived it, the sequents may in like manner finite themselves; that is to say, may be confluent into a similar figure, and may also actuate themselves; that is to say, may run out into surfaces.

3. *That the active of the second finite is the same with the second finite itself put into a state of liberty.* The active of the second substantial is no other than the second substantial itself (of which we have treated in Chapter IV.) put into a state of liberty, and thus rendered active. For if this substantial pressed upon nothing by contact, but were free from all contact and at its own disposal, then, in consequence of its having a derivative force similar to the one existing in the point and the first substantial, it cannot but in a similar manner render itself active and exhibit itself as the same with the active of the first substantial; for the origin of both is similar and the cause of their origin similar. Hence therefore it follows, that *the second finite becomes active, if there be no contact; and that the internal force of the second finite becomes motory, and passes into act if there be no pressure.*

4. *That the active of the second finite consists of individuals which are first substantials;* for it is the same with the second finite put into local motion.

5. *That the active of the second finite may derive its existence from the same causes as the active of the first.* With regard to the active of the first finite, we have above stated that it exists

from the contingency of the first substantials not being in mutual contact. The same contingent cause may exist for the origin of these actives of the second finite. The existence of actives supposes a space into which they may effuse themselves. This being given, the finites immediately actuate themselves; and evidently divest themselves of the nature of the passive.

6. *The active of the second finite possesses the same qualities as the active of the first.* Since all the actives are perfectly similar to each other, and owe their origin to the primitive force in the point to which they are consequently made perfectly similar, one active will possess the same qualities and forces with another. From the same and a similar cause proceeds the same and a similar effect. The active therefore of the second finite runs into surfaces of the same kind as the active of the first: this active acts upon the finites it meets in the same manner as the active of the first; it possesses a force proportioned to its velocity and weight, in the same manner as the active of the first, not to mention other similarities which it would be needless to recite.

7. *The only difference between the two is, that the active of the second finite describes larger circles than the active of the first; and that it does not flow with such velocity in its peripheries.* The circumstance of its describing larger circles follows from the ratio between its dimension and the dimension of the first active from which it existed. The dimension of the second active is larger: the distance of the centre of gravity from the middle centre is greater: the velocity of the centre of gravity is less: it therefore passes out into larger circles and moves more slowly than the first substantial. These results follow mechanically from the diversity of the dimensions.

8. *That the active of the second finite can be in the same space with the active of the first, provided the space be not too confined; but that the active of the first and second can more easily meet and encounter each other than pure actives of only one kind.* As we have above said, the difference between the two kinds of actives consists in one describing larger circles than the other; in one moving more slowly than the other; and one being larger and heavier than the other. These differences, which are differences only of degrees and moments, may occasion one

to encounter the other. For if all the actives were of one genus they could not easily meet each other; because the velocity of all would be equal; all would describe the same surfaces; and hence, in consequence of the equality of the motion and of the surfaces, one could not impinge [*nullus incursus*] upon another; but there might be a thousand in one and the same circular space, without impinging upon or encountering each other [*sine incursu & occursu*]. If however there be other actives which enter into this number and space, and which differ from the former both as to their circles and motion, then may the one easily come into contact with the other; the swifter may overtake and precede the slower; or may within a shorter time come to the same point to which the slower is moving. This it will do also the more easily, since the two differ as to the circles they describe; for the circle described by the slower crosses several of the circles described by the swifter, and cuts it as it were in different ways; consequently in several places, and at several different times, it presents itself to be impinged upon and encountered by the swifter active. If therefore the difference between the circles and velocities be great, the one cannot easily flow among the other; still although they become disturbed by encounters and impactions [*occursus & incursus*], they nevertheless can flow among each other in the same space, and all aim to settle into some equilibrium.

9. *That in regard to its mass the active of the second finite is stronger than the active of the first; but in regard to its velocity, it is weaker. Nevertheless the active of the second finite exercises a stronger impetus than the active of the first.* It is well known that active force and weight consist in the quantity of motion which results from the mass multiplied into the volocity; and that in any impetus the velocities and masses are reciprocally proportional. If therefore the active of the first finite moves more quickly than the active of the second, but the active of the second is larger in mass, the quantity of motion in each may be equal; and one may not therefore be compelled to give way to the other; for the mass of one may be as much greater as the velocity of the other. But because the difference in dimension and mass is greater than the difference in velocity, the smaller and swifter will yield to the larger and slower; as may be geometrically demonstrated. This however will take place

only when the particles encounter each other [*in occursibus*]. If however the smaller and swifter impinge upon one which is larger and slower, the larger is in some measure driven by the smaller *in altum*, or else from one place to another; although the motion of the smaller is, at the moment of impact, retarded. Now inasmuch as these actives move in a space which does not consist of contiguous particles, but is a vacuum where there is nothing to retard the motion, so also there is nothing in it to prevent one body from acting upon another with all its force and in perfect freedom. If in such a void, a smaller active act upon a larger, and *vice versa*, the action itself becomes immediately and instantaneously sensible in each; because there is nothing but the pure mass, or the parts which are in the mass, which offers any resistance in the space, or which tends to prevent each body from being sensible to the active force. *The medium itself in which they flow is none; hence the action of one upon the other is instantaneously sensible,* in proportion as the parts of which the active consists, allow of its existence.

10. *That actives of the same kind always flow with one and the same velocity; and that they cannot flow with a less or a greater. Consequently, that between actives of the same kind there are no degrees of velocity, but that there are degrees of velocity between two different kinds of actives.* The actives are now in their most perfectly free and natural state; there is nothing to restrain or hinder them; hence they move with all their force, having no more with which to move. And inasmuch as their liberty is nowhere restricted, they cannot move with a less degree of force; they always therefore possess the same velocity. Since the velocities of the actives of one kind are equal one to another, there cannot be any degrees between their velocities, but only between their own velocity and that of an active of another kind which moves more slowly.

11. *That actives of one kind always describe the same circles and gyrations, and cannot describe greater or smaller.* This follows for the reason just mentioned.

12. *That these actives do not form their circles or surfaces round one centre, but round several; that is to say, that these derived actives run out into surfaces or circles eccentric and not concentric.* For since the individuals of which the finite or

active consists, and also the individual parts of which the individuals are composed, endeavour to run out into spiral circles and surfaces; there is consequently a tendency of the smallest individuals to run into their circles, and of the next smallest or those compounded of the former to run into theirs. These tendencies and forces, operating collectively, cause the circles or surfaces which are described to be not concentric but perpetually eccentric. The more numerous are the composites of which any finite or active consists, the greater is the degree of the eccentricity of the surfaces which it appears to describe, and the greater their frequency. The most simple active however, such as the active of the point, can describe only concentric circles.

13. *That by means of this eccentricity the apparent surface of the active seems to describe a new and different surface, yet one proper to the active.* For if the active produce apparent surfaces, and at the same time moves its centre onward, the surface itself must also seem to move forward in the direction in which the centre moves; it thus appears to describe a certain circle; whence it would seem as if the active consisted of three dimensions, and as if it had a breadth equal to the diameter of its first surface.

Hence it follows, that *by the progression of their centre actives are transferred into every imaginable point of their space,* and move from one extremity to another; also that one active may represent a space most perfectly full, as much so indeed as if it were occupied by a legion. For since by its continual eccentricity the surface is translated from one place to another, and into some larger circle, it is hence superficially moved to every point in its space; and may thus carry itself into every point round about, forming [*quasi trudere*] a variety of figures and forces.

14. *That actives cannot be said to form anything contiguous or occupy any determinate place.* Place itself or locality is the relative of one contiguous thing to another. Place or locality obtains only in things contiguous. In the present case, however, the surfaces are only imaginary, apparent, and figured out by motion. There is only one real point in the whole surface, which can touch the surface of another. Hence there can be no contact of surfaces; consequently nothing contiguous; and for this reason no place, unless the actives were so

enclosed in one space as to have their boundaries in those which enclose the space; otherwise they could have no space; for the space is measured by the boundaries, not by the enclosed actives; so that space is a distance from one boundary to another; although interiorly there can be no distance from one active to another, or from the surface and centre of one to the surface and centre of another. Thus the diameter of the space cannot be divided into smaller degrees or distances, except relatively to contiguous particles which are out of the space; that is to say, except in an imaginary manner.

15. *That actives are devoid of all determinate place and situation, unless they are enclosed by finites or elementaries.* Unless the space consisting of actives were terminated in some surface consisting of finites or elementaries, the actives could not be enclosed, and thus could not form a space. For by reason of their eccentricity they run out into all space; nor do they ever return to it without completing a second, third, or fourth circle, according as their circulation is either of a fewer or of a greater number of dimensions. And inasmuch as they are thus nowhere enclosed, neither can they naturally be translated into any place, and at the same time into some different motion, except by means of a surface consisting of finites.

That actives have nowhere, in their enclosed space, the relations of upward or downward. Upwards or downwards or directions to any particular quarter result solely from contiguous elementaries, and from the motion and situation of the particles in contiguity. In the present case there is no medium, much less any contiguous medium; nor any disposition of a contiguous medium by motion. Therefore in the space of these actives, as also in the peripheries which they configurate, they cannot be said anywhere to tend either upwards or downwards. But wherever they are in their peripheries, there also they are in their position of above, below, and sidewise, all at the same time; to them the perpendicular, horizontal, and oblique are all one: these peripheric boundaries are clearly unknown in the active space, and are there confounded one with the other; consequently in this active space neither is there any weight. The largest active space has the same weight with the smallest.

16. *That actives cannot be said to resist but only to act.*

Since they form nothing contiguous, they do not resist but only act; resistance belongs only to what is contiguous. Inasmuch also as actives flow in no medium, they are displaced by the slightest encountering force [*occursum*], and sent out of their own surface into another; nor is there anything in them which can offer the least impediment, except their mere velocity and weight. Since therefore they act merely by figure, velocity and mass, they cannot be said to resist.

17. *That no number of actives constitutes an element or matter; nor are the actives themselves to be considered as elementary particles.* Inasmuch as they form nothing contiguous, so that they can collectively be moved and pass contiguously into a similar motion; inasmuch as they cannot actuate any volume into motion, or occupy or fill any place, or do other things which are essential to an element; they cannot possibly be considered as elementaries. In their figures there is almost nothing real, there is only what is formal; hence they cannot be called material.

18. *That the force of the active space is increased, and becomes the stronger according to the number of actives.* If there are many actives in one space, there are many entities which act, or many active forces; and if anything comes in their way, not only do a great many actives act upon it, but upon all its parts, at every angle; and turn and move it in any and every direction. Thus the more actives there are, the more multiplied and consequently the stronger is their action upon anything that comes in their way.

19. *That a space filled with actives of the first and second finite, acts more strongly than if filled with actives only of one kind.* The active of the first finite acts by its velocity upon what it meets; upon a smaller composition but similar to its own. The active of the second finite, however, acts both by its velocity and weight; so that it possesses a greater impetus, and can thus act upon a larger composition or one consisting of more parts. Since therefore each acts by velocity, and one also by its weight more than another as likewise by a larger figure than another, it follows that both kinds of actives together can act more strongly than only one kind. For there are compositions of finites which require to be acted on both by velocity

and weight; and which can be moved only by the actives which are heavier in weight.

20. *That the solar ocean seems to consist of the actives of the first and second finite.* For these actives it is which are the causes and origins of all the ulterior mutations and compositions which occur in our nascent world, and by which alone the first and second elementary particles can be produced: unless there were some large space filled with actives, their sequents could not be produced. As yet however no other actives are afforded than those of the first and second finite; it follows therefore, that it is of these that the solar ocean primitively consisted, and continues to consist even to the present day.

ACTIVES OF THE THIRD FINITE.

The primitive force in a point continually produces similitudes to itself, by the multiplication of itself into itself, whenever occasion offers; and the force can go out into act. It has been above shewn, that by the mechanism of its motion and perfectly regular and geometrical figure, the primitive force in a point cannot but produce likenesses to itself, and continually derive them into their sequents. Consequently, that a substantial thus arising cannot but be perfectly similar to the point, and possess a perfectly similar power [*vi*] or a power of producing sequents in like manner. There may therefore be substantials which by their multiplication into themselves, and thus by being frequently compounded, are elevated into higher powers. So that if the first point were considered as one, and a 100 points constituted one smallest substantial, the second substantial would consist of 100 first substantials, or of 10,000 points; the third finite would consist of 100,000 points; the fourth finite or substantial, of 100,000,000 points; the fifth, of 10,000,000,000 points; and so on by a continual multiplication of the substantials into themselves. And since the actives are the same with the finites or substantials in a state of liberty, it follows that one active must consist of the same number of points. Hence

the third active consists of 100,000 points, or 10,000 first substantials; and so on. This number I have fixed upon only by way of example; for we cannot tell what may be the number which at first has to be multiplied into itself.

2. *That the active of the third finite is the same as the third finite itself in a state of liberty.* Of the third finite we shall soon treat in the sequel; as also of the manner in which it arose from the compression of the elementary particles, and was thus made similar to the second finite, the first, and the point.

3. From the same causes also it follows, that *the third finite is rendered active, if there be no contact with similar finites;* just as is the case with the preceding finites.

4. *That the velocity of the third active is less than the velocity of the second, and still less than the velocity of the first;* as is evident from what we have already stated in our theory of the active.

In the same manner also *the circles and superficies which the active of the third finite describes, are larger than the surfaces or circles of the active of the second; and still larger than the circles or surfaces of the active of the first.*

Moreover *the mass in the substantial of the third active is larger than the mass of the substantial of the second active;* for it is composed of second finites; and so on a hundred times over, if it be not larger than the active of the second.

5. *That the active of the third finite acts both by its mass and velocity; and that it is stronger in acting than the active of the second.* For since the quantity of this motion is greater than that which is in the active of the second, it follows that the active of the third acts by both, namely, the mass and velocity, more strongly than the active of the second. For the greater velocity in the active of the second cannot be in the same ratio as the larger mass in the active of the third. Consequently if the velocity of the active of the third be multiplied into its mass, and the velocity of the active of the second into its mass, there results a less product or a smaller quantity of motion in the active of the second finite, than in the active of the third. With regard to weight, it does not appear that we can speak of it as predicable of the third finite; but instead of it we substitute mass; for there is no medium in which the

finite flows, and consequently no weight can be perceptible; inasmuch, however, as it consists of larger individual parts than the active of the second finite, and consequently of a larger mass, it follows that if it experience impact in any manner, the mass with all its individual parts is immediately sensible of the impetus; and before this sensibility *(sensus)* reaches all the individual parts, the mass shews itself incapable of being moved. In relation therefore to the communication of impetus with its individual parts, a something similar to weight and resistance is presented to us.

6. *That the active of the third and second finite may be simultaneously in one space.* This follows from the reason above mentioned; namely, that the active of the second and first finite may move simultaneously in one and the same space. In consequence of the difference between the velocities and the circles, various impactios and encounters [*incursus & occursus*] are originated, and although these may happen to actives of both kinds, yet these actives are not for this reason driven out of their space, but may after collision perform their gyrations the same as before.

7. *That the actives of the third and first finite cannot be simultaneously in one and the same space; since, in consequence of the difference between their velocities, circles, and dimensions, the circles and fluxions of the first active would be thrown into utter confusion, and either these would be expelled thence or else the active would become absorbed.* Their inability to move in one space arises from the difference between them as to velocity, figure, and dimension. The velocity of the third active is much less than the velocity of the first; hence not only does the active of the first perpetually impinge upon it, but also encounters and impinges [*occurrere & impingere*] upon it every moment. For since they differ in the circles they describe, the active of the third finite forming larger circles than the active of the first and consequently crossing over numerous surfaces of the active of the first, it must necessarily happen, that they are almost everywhere in collision. Inasmuch also as they differ in dimension and mass, so much so indeed that the active of the third finite is nearly 10,000 times larger than the active of the first, it follows that the impetus of the first active, as exercised upon

the active of the third, is but small; and that the active of the first may be impelled and driven about by the active of the third in every direction. Now since this collision is perpetual, the actives which possess a smaller degree of force and impetus are compelled to abandon their place, and are driven away in another direction. If moreover we contemplate the texture of the active or of the third finite, we see it consisting of individual parts which are second finites or substantials; and consequently the interstices between every individual are so large that the active of the first finite can flow into them, and become entirely secreted in them; and in consequence of the collisions being so frequent, the actives of the first finite may possibly flow into the interstices themselves, and may thus become absorbed and entirely disappear. Consequently there cannot remain in one space actives which are much different from each other in dimension, velocity, and in the circles they describe.

8. *That by means of the influx of the actives of the first finite, the actives of the third may ultimately lose their active force.* Since in the active of the third finite the interstices are so large and widely open, that the active of the first may flow into them and bury itself, so by their continual influx these interstices may become filled, and the motion of its individual parts be more and more impeded; till at length, by the multiplication of these entities, it may be entirely destroyed. For a perfectly regular motion cannot be preserved except by and among perfectly similar corpuscles; this motion, by the intervention of such as are dissimilar, is impeded, and as it were under restraint, and consequently becomes irregular. Now with the destruction of this regularity all its active force is destroyed; a force which consists only in motion and in the regularity of motion.

9. *That there are in the world no actives of the third finite; but that they are all third finites, and compose the surface of the second elementary particles.* For since they cannot move in the same space with the actives of the first finite, and since the large active space or solar ocean consists, according to our hypothesis, only of the actives of the first and second finite, and since the three cannot be simultaneously in the same space; it follows, that in this large space there are no actives

of the third finite, nor are there any in the elementary particles of which we shall speak in the sequel; hence they must remain passives and finites, and occupy the surfaces of the elementary particles; hence also they contribute to the composition of new elementaries, and perform their functions in the surfaces of these particles.

CHAPTER VIII.

THE THIRD FINITE OR SUBSTANTIAL.

Before the world with all its elements and parts was formed, and brought to the perfection and beauty in which we now behold it, it was requisite not only that it should undergo a vast variety of changes, but that its parts should be multiplied one into the other in every diversity of manner. For the world could not consist or be formed and perfected out of a simple and single element, nor out of a simple and single active, nor out of one or two substantials; for in this case it would be perfectly simple, and pregnant only with first principles; by means of which alone no ether, fire, air, or anything else could ever come into visibility; these principles therefore must first pass through a variety of changes and multiplication. For had the world remained in a state of first principles and perfect simples, it could not possibly present to us such a diversity of phenomena as it does; nature could not have acquired such various methods of unfolding her forces, and of representing herself to our senses with an aspect so joyously and delightfully varied by images, or by other means derived *à posteriori*. Nature would have been in possession of a vast empire destitute either of inhabitants or subjects; in fine she would as it were have reigned alone in her own vast and empty courts. She would behold no kingdoms in subjection to her to which she might give laws; no elementary and much less any mineral, vegetable, and animal kingdom. For the visible world is a series of finite things both simultaneous and successive; modified and connected one with the other in a multiplicity of ways, and in a long extended order.

There is no kingdom of the world but requires that nature, by the operations of her forces, should be frequently multiplied into herself, and have one part of herself derived from the other, so as thus to experience augmentation. Hence nature could not stay her course and rest in those principles we have hitherto been explaining, but must progress still farther by increased multiplications, derivations, and dimensions of her parts and their compounds; so that *the more numerous the genera of finites, actives, and elementaries successively arising by multiplication, the more enriched, beautiful, and perfect is the world.*

1. *That consequently, the third finite or substantial is that, which, as to its origin, parts, figure of parts, situation, motion, and so forth, is perfectly similar to its preceding substantials or finites, or to the second finites, the first, and the point.* For not only are all the finites perfectly similar to each other, but also all the actives and elementaries. Nay, even their composites or entities multiplied one into the other, or derived from their individual components, do not differ from each other in regard to figure, situation, or motion; but only in dimension, space, moments, and degrees.

2. *That therefore the third finite consists purely of second finites;* or, the individuals or parts of the third finite are purely second finites; the individual parts of these individuals again are first finites; the individual parts of these again are simples, of which we have spoken in Chapter II. This third finite is consequently no other than a simple or point multiplied thrice into itself or raised to its third power.

3. *That inasmuch as this finite is similar to its antecedent finites, and is a third generation from the points, it is of the same quality with its antecedent finites.* The individuals of this finite are consequently connected as to their poles, and are disposed into a spiral order, situation, and flexure. The compound has thus a figure perfectly similar to that of its component parts; the poles and polar cones observe the same figure; as also the larger and lesser circles on the surface. Hence arises a force and conatus tending to an axillary, progressive, and local motion. Thus also does the compound, succeeding the former finite, come into the same power [*vim*] and quality of being passive and active, and being similar to the former as to a state of inertia

and partly of activity; as likewise into the same power and quality of producing a new finite, active, and elementary. This finite therefore is the same with the forementioned; but presenting the appearance of larger dimensions.

4. *That this finite derived its origin from the first elementary particle in its state of highest compression, and near the large active or solar space.* All the second substantials, which are its individual parts, are now not collected into one aggregate, but form a surface and expanse of particles; they are passives, but constitute, together with their enclosed actives, a new genus of particles; that is, of elementaries such as we have already explained. This finite therefore derives its origin from the elementary particle; for it is the same with the elementary particle in its most highly compressed state, and into which the actives had vanished in consequence of the compression. Let us revert to the theory of the elementary particle. We have said that these particles may be expanded and compressed; that under a state of compression they become very similar to finites; that they ultimately cease to be elementary; and that actives, when banished from their localities or reduced within a narrow compass, become finites or substantials. With regard to the mode in which this is effected, we have said, that by means of compression the elementary particles retreat into a less space, and as it were into themselves; that their surface becomes multiplied three or more times, and ultimately into as many series and orders as there are spiral surfaces in the finite; that in their highest state of compression they more and more divest themselves of their elementary nature, and more and more become like a finite; until the whole of their elementary nature becomes changed into that of a finite, their elastic into a hard nature, and their highly yielding into a stubborn resisting nature. Now this can occur in no other place than round the large active space, in its vortex. Imagine this active space, or the sun, surrounded with a large volume of elementary particles, and its action upon the volume or circumfused particles to be continual: imagine also a certain vortex to be not as yet formed, but to be in a state of formation. In consequence of an action so immense, it is not possible but that the proximate elementary particles will be most

violently urged, moved, and solicited to action, as also all the others next to them for some distance around. Those which are nearest to the sun are in the first and greatest degree of action; the others, in proportion as they are farther removed, are in a less degree; consequently they are in a greater or in a less degree of compression according to their distance. For since a vortex is not yet formed, but is only in a state of formation, there is a renitency and disobedience to one and the same general motion. For all the particles are in the same degree of expansion; all, upon any given action, tend to the same circle and gyration: one therefore tends to press and impel another to the performance of the same circle with its own: each urges the adjacent; and thus the action extends to a considerable distance from the sun, till all, by its continued existence, are reduced by motion and compression to their natural state. Thus the particles which are nearer the sun and more compressed, tend to a smaller gyration than those which are farther off and less compressed. In this situation and state of compression, proportioned to the several distances from the sun, they flow naturally with unimpeded current and with a general consentaneity: the force inherent in every particle directing the motion; and the solar active space, by its action, maintaining the particles at every distance from it always in a similar and proportionate state and degree. Before therefore the vortex is so formed that the particles, according to their distances from the sun and their degrees of compression, flow by a spontaneous effort into a general vortical motion, it must necessarily happen, that those which are nearest to the large active space retire into smaller and smaller dimensions; and are so compressed as to be deprived of all their elementary quality, and to become entirely third finites.

5. *That from these third finites there may arise again new elementary particles:* for these particles are similar to the antecedent finites which constitute the surface of the elementaries. They originate near the large solar space where are the actives both of the first and second finite; and they can act with a greater strength on the finites of higher power or larger dimension. They have the same place of origin, and a similar

cause; hence they are expanded and elevated, like the second finites, into new and similar elementary particles. Of this, however, we shall speak in the following Chapter.

CHAPTER IX.

OF THE SECOND OR MAGNETIC ELEMENT OF THE WORLD; THAT IS, OF THE NEXT ELEMENTARY PARTICLE COMPOSED OF THIRD FINITES AND OF THE ACTIVES OF THE SECOND AND FIRST FINITE. OF ITS MOTION, FIGURE, ATTRIBUTES, AND MODES. THAT THIS ELEMENT, TOGETHER WITH THE FORMER, CONSTITUTES THE SOLAR VORTEX, AND IS THE ONE WHICH PRINCIPALLY CONTRIBUTES TO THE PHENOMENA OF THE MAGNET.

ANOTHER and a new element comes now into our simply solar world. Unless there were elements crowding round the sun, there would be nothing upon which it could exercise its action; and through which it could extend its sway into the remotest and most widely scattered regions. Without elements the active space would be as nothing; it would be a centre without circumferences; an active without passives; a soul without a body; a space without place; the eye would have no quarter toward which to look; there would be no upwards, downwards, or sidewards; in fine, without a termination in elementaries there would exist nothing; but everything would relapse into its pristine inanity. For this reason the solar ocean is surrounded with new and additional elements, by means of which Titan can elongate his rays, and extend his arms and sceptre into the remotest regions. The quality, however, of this new element and the parts of which it must consist, result from their connexion with its first principles, and from the same mechanical and geometrical necessity as pertains to the others we have been considering.

1. *That the second elementary particle consists of third finites, and of the actives of the second and first finite; that also the fore-mentioned finites occupy the surface and the actives the internal space.* The third finites which had entered into the world, and of which we have spoken in our former Chapter, were near the sun or the large active space of the vortex; consequently they cannot remain finites, because they are near the active space; but must necessarily be convoluted and conglomerated into new surfaces, in the same manner as are the second finites into first elementary particles. For according to our hypothesis, the first elementary particles next the sun, are most highly compressed; and, in consequence of the compression, cease to be elementary, and exist as finites of the third genus; and since they are thus proximate to the sun, it follows that they are put into operation by its actives, and are in like manner convoluted into new and elementary surfaces; these surfaces being occupied by finites and their internal space by the actives of the sun; just as water is carried by the ether into vapor; and other liquids, when placed over the fire, converted into bubbles.

2. *That the second elementary particles are, both as to their origin, figure, surface, and space, perfectly similar to the first elementary; that they differ only in regard to dimension; for the second elementary particles are larger in space and surface, inasmuch as they consist of larger finites and actives.* With regard to their origin, these second elementary particles take their rise near the solar ocean or large active space; namely, where the actives of the second and first finite are, or where the actives are enabled to operate and act immediately upon the finites, to reduce them into subordination, and not to cease before they come into a state of equilibrium; the finites constituting the surface, and the actives occupying the space within. In this manner it is that the first elementary particles arose, as we have previously described; and hence we find a similarity between the two, in regard to their origin and existence. The second elementary particles are also perfectly similar in regard to figure; for if in both elementaries the finites constituting the surface are similar, as also the actives occupying the internal space, there must result a perfect similarity in figure, and an

equilibrium between the two. They must therefore be perfectly similar in regard also to surface and space. The only difference between them is one which is common to all the products of nature, whether finites, actives, or elementaries; namely, that the second or derivative are larger in dimension than the first.

3. *The second elementary particles possess the same elasticity as the first.* From a similar cause arises a similar effect. If the finites occupying the surface, if the actives occupying the space, and if the figures be similar; then there must be also a similar kind of yieldance and elasticity. For in this case likewise the surface lies expanded between two forces, and in a situation perfectly natural to it. Interiorly are the actives, which only act but do not resist; although, by acting not only upon one but upon all the parts, they resist as it were or react. Hence also it follows that the resilience of the surface is equal to the pressing force; that it recoils and reacts with the same force with which it is pressed; that the sum of the forces before and after the conflict is the same, or that the same quantity of forces is preserved in every collision and compression; that the surface, when liberated from the compressing force, is immediately restored; that its degree of weight is imperceptible, in consequence of which it cannot be said to lose any; and that in the expanded particle we must conceive of the impetus as the smallest possible, or as none. That in this particle there may be all the degrees or species of elasticity; but this only according to the degree of compression. Not to mention other predicates of the first elementary particle, in respect of yieldance and elasticity.

4. *That the second elementary particles may be compressed and expanded in like manner as the first. That their centre of gravity is in some part of the surface, and when in a state of compression is nearer the interiors than in a state of expansion. That in like manner these elementary particles have an axillary motion, and collectively a tendency to a local motion. That the particles which are nearer the sun and are in a greater degree of compression, tend to a lesser gyration and circle; and those which are farther from the sun or in a greater degree of compression, tend to a greater. That in virtue of the effort exercised by each, and a certain degree of accessory force from the active and central*

space, they spontaneously conspire to the vortical motion the most adapted to them; a motion which, by reason of the action of the sun and the force and effort inherent in each particle, they perpetually preserve; not to mention other particulars which we have already predicated of the first elementaries. For if the centre of gravity be in the surface of the elementary particle; and if, by reason of the effort made by the finites constituting the surface, it be continually rotated round the axis, it follows that, from the common effort of all these, there exists an effort of the elementary particle or compound to a certain gyratory motion. Inasmuch also as the centre of gravity recedes in a compressed particle more towards the interiors, and the axillary rotation is swifter, the particles, when compressed, tend to a smaller gyration than when dilated; and if their degrees of compression are according to their distances from the sun, there is a general consent and effort of all to the same vortical gyration; into which they are also perpetually sent by the vortical motion.

5. *That the surface of the second elementary particle is exactly equilibrated between two forces; that interiorly it is pressed by the active force, and exteriorly by the first elementaries.* No surface could subsist without an equilibrium formed by the forces on either side: there must be as great a degree of action on the convexity of the surface, as on its concavity. Exteriorly are the first elementary particles, possessing the highest mobility, and elasticity; exercising a pressure in proportion to their altitude, and being capable of acting on the convex surface, as also on the convex part of the polar cones: interiorly are the actives of the first and second finite, acting. Hence the surface is naturally balanced between the two forces; tending neither inwardly nor outwardly, but lying suspended between them; and exposed to every supervenient external motion, yet the similitude of the figure being preserved in every case, and under every state of compression.

That the first and second elementary particles may concordantly flow in one volume, sphere, and vortex. Although they differ in dimension, and although the second are larger than the first, nevertheless inasmuch as they are perfectly similar in figure, elasticity, axillary motion, and effort to local motion,

there is nothing to prevent them simultaneously flowing in the same volume, and by a unanimous motion forming the same gyre and vortex.

6. *That these second elementary particles are in like manner pressed by others incumbent upon them; and that the pressure of the incumbent particles is proportioned to their altitude in the plane of the zodiac, and also to the area subjected to the pressure; provided their volume be reduced by motion to a regular and vortical situation.* This follows from the reasons which have been alleged in the theory of the first elementary.

7. *That the third finites constituting the surface of the elementary particle conjoin themselves and become passive, in a manner similar to that of the second finites in the surface of the first elementary particle.* If there be a like figure and situation of the parts, there will be a like conjunction and connexion of parts; if the figure be spiral, if there be poles or polar cones, and if there be spires traversing the surface obliquely and extending from one pole to another, it will follow that the conjunction of all will be so reciprocal and close that one cannot be moved without the other; that a change of state in one implies a change of state in the other; that if one have an axillary motion so must the other; not to mention other particulars which we have stated in our theory of the finites or surfaces belonging to the first elementary particles.

8. *That the finites constituting the surface, like the finites of the first elementary, turn their convex and lighter part toward their internal space; and that they are thus compelled to cohere as to their poles.* The enclosed actives are themselves of the same nature and character, because they always act upon the concave surface; and wherever they meet with anything angular or unequal, they assail, turn about, and disquiet it until that part is opposed to them upon which they cannot act. The convex part of the finites is that upon which the least action can be exercised. This however is not the case with the part where the poles are. There is therefore a certain mechanical necessity, that the finites should be connected, as to their poles, in the superficial expanse of the elementaries. Nor can their sides be conjoined in any other manner; inasmuch as their active space prevents them from taking any other situation.

9. *That the motion and essentials of the volume are similar to the motion and essentials of the parts in all the elements, and reciprocally.* For all the elementary particles are moveable of themselves; and, inasmuch as they are elastic and most highly yielding, there cannot be any motion of the volume or any common motion without a motion of each particular part. There is no such thing as motion in the volume, without the individual parts conspiring and consenting to the motion; so that the motion of every part contributes to the general motion. Hence it follows, that the whole motion of the volume is most perfectly accordant with the motion of each part; that the figure of the motion of the volume is perfectly similar to the figure of the motion of each part; and that the elasticity of the volume is perfectly similar to that of the parts composing it. Thus from the modification of the whole or of the volume, may be concluded the nature of the figure and motion in each part. Such is the characteristic which distinguishes the elements. Nothing can occur in the volume and its compound which is not perceived individually in each particle; nor is anything perceived in any individual particle which is not rendered sensible in the volume at a distance. The contrary is the case in things hard and substantial; the parts of which cannot be moved separately, but must all be moved simultaneously with the compound. Hence from the phenomena which occur in elementaries we may easily draw our conclusion with regard to the essentials of every individual and part; and from the parts again we may draw our conclusions with respect to the volume.

10. *That the second elementary particles may be compressed into their smallest compass, in the same manner and by the operation of the same cause as the first elementary particles; that in their highest degree of compression or nearest the large active solar space, they change into new finites, which may be called the fourth finites and are similar to the preceding.* That they are susceptible of compression is beyond a doubt; inasmuch as they are yielding, elastic, and similar to their first elementaries: those also which are nearest the large active solar space are in a higher degree of compression than the more distant; and these degrees of compression are in the ratio of the distances, or as the vortical circles round their centre, inasmuch as their

forces and efforts tending to their circle or gyration are according to the distances and consequently according to the modes of compression. Let us therefore again conceive a solar vortex not as yet formed, but as in a state of formation; having an incipient vortical motion, but not yet habituated and wholly given to it. In this state the elementary particles are not yet compressed according to their distance; nor are their efforts and forces in the same ratio, namely, that of their circles which they describe. Hence we must conclude that in this state of incipiency and formation of the vortex, the particles next to the solar space would be exposed to the greater and more immediate action, while the others would be acted upon in the ratio of their distances. The particles therefore which are proximate to the solar space are in the highest degree of compression; and can be reduced into the smallest compass, or into pure finites. After however the vortex is formed, and every particle is compressed in the ratio of the distances, it does not appear to be mechanically possible for any compression to be carried on still farther into some ultimate, and smallest corpuscle or finite. That when the vortex is formed these second elementary particles will have receded to a distance from the solar active space, we shall have to shew in the course of our future observations.

11. *That in every particle of this elementary kind, is reposited everything in the world which has hitherto arisen from the point; and that every elementary particle is a least compendium of the preceding world and its entities; that there is thus a most perfect harmony between the parts and the compounds; and a most close connexion of all with the first.* All the preëxistent finites and actives concur in composing this elementary particle. The point itself is the simple of all the finites, actives, and elementaries, and consequently it has entered into the substance of each. The second finites are the parts and individuals of the substantials following, or the second and third. The third finites therefore occupy the surface; in these are the second and first finites, and the simples. Within the surface are two kinds of actives, namely, those of the first finite and of the second. The first elementary particle itself, compressed as to its surface to the utmost and into the third finite, composes this elementary particle as a finite. Hitherto however it flows extraneously as an

elementary particle, and keeps the surface of the first elementary particle expanded and equilibrated with actives reacting. Thus in every part of the world, is latent a world; in the microcosm lies the macrocosm; in the least is latent the greatest; the whole vortex in its smallest part, with all the substantials, essentials, and modes. The motion of our large system is latent in a least system; so also is the figure; whence in largest things, as in least, the world is similar to itself. Its least part is a type of its greatest; its greatest is an image and effigy of its least. Thus it is that the world keeps together in virtue of a most perfect harmony between the parts and the compounds.

CHAPTER X.

ON THE EXISTENCE OF THE SUN AND THE FORMATION OF THE SOLAR VORTEX.

No longer dwelling merely upon parts and individuals, we shall now proceed to compounds, large spaces, systems, and the world itself; from the goal we shall issue forth into the open plain; and, from the principles already laid down, contemplate the existence of the sun and the formation of the vortex round it; both of which are reposing as yet in a state of infantile existence. Inasmuch however as we now come to treat purely of contingents, causes must be partly conjectured, and partly derived from the connexion existing between our principles. That no portion of our subject however may be left untouched, but that our system may follow the principles laid down, and observe an unbroken series, and orderly sequence, we shall now add a few words on the existence of the large solar space and its vortex.

1. *According to the tenor of the foregoing principles, the large active solar space could primitively have consisted only of the actives of the first finite.* That the solar ocean existing in the middle of the vortex is the fountain of all the motions which take place between the parts constituent of the world, is, I imagine, perfectly clear; as also that it is, as it were, the soul of its immense body and system, and a perfectly active centre, around which the smaller and larger parts are whirled in a perpetual current. If therefore there be a largest and most active space, then, according to our principles, it could primitively consist of no other than the actives of the first finite; for it is necessary that, in coming forth into a world, the actives should

proceed successively and by gradations of time, without which the chief principle of entities truly natural would be wanting; and the world could not be perfected. Hence, if there be a perfectly active solar space, consisting solely of actives, it cannot consist of any other than the actives of the first finite.

2. *That no space or place can be occupied or enclosed by actives, unless it be surrounded by finites, in which alone it can be terminated and limited; and consequently in respect of which it can be called a space.* Actives of themselves enclose no space, except in relation to the circumambient finites. Space and place are relative to what is contiguous: they can exist only in a contiguous extense from one individual to another, as from one limit to another; for space is always limited, figured, and terminated in real entities. Actives however form nothing contiguous either from one centre to another or from one surface to another; consequently no degrees or moments can be reckoned among actives; nor can any fixed limits be established. They are only the ideas, phantasies, and effigies of figures and surfaces: they are corpuscles only in appearance; which describe not one but an infinite number of centres, and an imaginary surface not in the same but in an infinite number of places. Hence of themselves they enclose nothing, and limit nothing; but are themselves to be enclosed and limited. We can therefore conceive of no solar space without surrounding finites or elementaries. If therefore there be a solar space, and in its middle the most perfect activity, then, according to our principles, it could not, in this primordial state of things, be surrounded with any other than the finites of the first active, pressed all around into a narrow compass by the action of the space.

3. *That by the immense action of this space the surrounding finites can be reduced into such a situation, that one may be in contact with the other; and consequently enabled to finite themselves; and by means of motion one among the other to flow into second finites.* This likewise follows from what we have said. For if the fore-mentioned finites give limits to the space, and confine the actives within given barriers; they must necessarily become reduced to such a situation as mutually to conjoin their sides by contact, and so closely to touch each other, as, accord-

ing to our theory of finites, mechanically to finite themselves; and, by forming a new compound, to multiply themselves. Hence we derive the origin of the second finites.

4. *Consequently, the second finites now surround and enclose the same solar space; although the first finites, for the forementioned reasons, coalesced into the second. In the same manner these second finites, which are now proximate to the solar space, may, in a considerable number, enter into the space and become actives.* The solar space may thus be enriched and distended with actives of two kinds; being now supplied with the latter in addition to the former; and thus may its power be increased of acting upon the surrounding or inclosing particles. For if any finite should escape out of its volume, aggregate, or expanse, into a space not consisting of contiguous particles, it is immediately rendered active; because it possesses the power of actuating itself. Thus may the solar space increase by means of a new genus of actives, and act with a stronger force upon the surrounding particles.

5. *That both the first and second elementary particles may now take their rise round this large active space; and may successively form a sphere which gradually grows larger; until at length they suffice to form a certain large vortex round the sun.* For the entities of each kind are present, both actives and passives, of which the elementaries consist; since in the solar space are the actives, and round about are the finites, which consequently coalesce into particles and compounds partaking of each; and which, inheriting the force and character of each, derive into themselves both the active and passive principle. Thus it is that, everywhere in the world, they are present; everywhere they move and are put in motion; they occupy and are occupied; they act and are acted upon both as to their distinct particles and as to their entire volume; and, possessing as they do a most yielding, mobile, and highly elastic surface, they can flow equally under the pressure of a large as of a small weight. In a word, thus it is that in general [*fere*] they may derive their origin in the confines of the active space, where an abundance of each principle is to be found; just as in virtue of these two principles, vapors and drops arise on the confines of liquids; a volume consisting of actives occupying the internal space, and

a volume of elementary parts pressing without; for elementaries can never constitute the surface of any particle, and be put in motion superficially, like the finites.

6. *That in the state of the formation of the vortex, among the elementary particles, as they are growing by accretion into an immense sphere or volume, no other force was needed than a certain active centre;* and that otherwise the elementary particles themselves would spontaneously dispose themselves into a general motion conformable to the figure of the parts; and that, by means of the action which takes place in the centre, they would perpetually continue this motion both as to each particle and also as to the whole volume.* If, in a sphere of elementary particles, there be a centre of motion or an active centre, the parts which are nearest the centre come into a state of greater compression than the parts which are more remote; consequently there is an attempt of each particle to flow into a gyre produced by its compression; the degree of which is proportioned to the distance from the centre. Without a centre, all the motions would flow into the same circle; and indeed into the greatest of all, or into a right line; but none into a lesser, and then proportionally larger, or into a common vortical motion; for they are all, in their greatest degree of expansion, without action or without a space acting. Hence if there be a centre and a force of activity in the centre, the elementary particles dispose themselves, by a mechanical necessity, into gyres conformable to their distance from the centre; that is to say, into a vortical motion.

7. *That the sphere of the elementary particles flows, entirely from the action of the solar space, into a vortical motion; and that this motion must accord with the equators and poles of the parts; and hence must extend itself into a spiral figure at a considerable distance from the centre; and must consequently by the fluxion and situation of its particles form a zodiac, &c.*

8. *That elementary nature is similar to herself both in the greatest and least things; in the macrocosm and in the microcosm; in a heaven and in a small volume; in a world and in a particle.* In fine, we may perceive its form and effigy to be the

* It is desirable to ascertain how far this theory will account for the formation of suns out of nebulæ; and for the active centres which these nebulæ present.—*Translator.*

same, in the largest mirror as in the least; it is visible however to the eye only in a large one, *i. e.* not in a simple but in a compound. Nature is a motive force diversely modified; a motive force diversely modified is mechanism; mechanism is geometry acting, since it cannot be otherwise than geometrical; geometry is an attribute of every ens endowed with figure and space; it is consequently inseparable from every individual and compound, whether at rest or in motion; it is inseparable also from motion itself. Hence throughout the world it follows nature from its first origin, seed, and egg; from the least dimension to the greatest; and inasmuch as geometry is the same in the greatest things as in the least, hence also nature, so far as it is a motive force and modified, so far as it is mechanical and geometrical in either extreme [the infinitely large or infinitely little] is perfectly similar to itself. Hence we may contemplate the whole world in a volume; a volume in a particle; a particle in an individual; an individual in a simple; and reciprocally a simple in a compound; a compound in a volume; a volume in a world; a world in a heaven; proceeding thus from the infinitely small to the infinitely great. Nature therefore is largest in what is least, and least in what is largest. And inasmuch as the world is not visible except in things large and compound, we may hence draw conclusions from the large to the lesser, and the least; as also from the large to the larger and the largest. The same parts and elements are in the least things as in the largest; in a small volume as in the great heaven. If the causes are like, there will result like causates. Such as are the principles, such are the principiates. They cannot be varied as to effects unless they are first varied as to causes. If the same causes remain, the same effects will present themselves. If *a* be a cause and *b* an effect, then if there be a thousand times *a* there will be a thousand times *b*; and a thousand times *a* to a thousand times *b* is the same ratio between the causes and effects as that of *a* to *b*. Thus from the particles we have above described, or from a minute volume of these particles, we may learn the nature of the starry heaven and of the large solar vortex; from the lowly hovel we may ascend to the palaces of the skies, with all their sublime and magnificent courts; from the dust, to the stupendous arch of heaven studded with so

many, and such mighty stars, and enriched with such beautiful ornature. Before however we can venture to elevate our minds to the contemplation of this subject, we must first turn our attention to elementary nature, as exhibited in her lesser heaven and world; or in the volumes and sphere surrounding the magnet.

END OF PART I.

THE PRINCIPIA.

PART II.

THE PRINCIPIA.

PART II.

CHAPTER I.

THE CAUSES AND MECHANISM OF THE MAGNETIC FORCES.

In the former part of our Principia, we arrived at that element of the world which may be denominated the magnetic; the first in which elementary nature presents herself as visible to the eye. Here it is that she begins to emerge out of her hiding place, and from darkness to issue forth into light: here it is that she discloses to view many of her mysteries; that she presents an image of herself as a whole: that at the very first glimpse of herself, she overwhelms as it were and confounds our senses by the forces with which she has invested a rough, dark, vile, and heavy corpuscle. This corpuscle is the magnetic stone; which may well be called the *lapis lydius* or touch-stone of the learned; which to the minds of philosophers has been as much a source of perplexity as it has been to their senses one of delight, and to both a subject of admiration. Here it is that phenomena first begin to present themselves, and that we have the opportunity of making experiments; by which, as by a touch-stone, our principles may be tested and their truth ascertained. We may here see whether they are as much in harmony with actual experiment, as they appear to be with the principles of mechanism; and whether our principles can be confirmed by experiment, the prior by the posterior, the unknown by the known. Principles cannot be better tested than by weighing them in the balance against ascertained facts. In the first part of my work, I have had occasion to observe that I had formed principles without the opportunity of making experiments; that I had nothing to appeal to in proof of my propositions, before I had advanced to another mundane element;

that if there were a mechanical connexion extending in orderly sequence from the first point to this element, and if the theory of this element could be confirmed by experiments, these also would confirm the theories of the antecedents, in virtue of their connexion with this element. At this element, then, we have now arrived: we have now placed ourselves in a world which is rendered visible by phenomena and experiment. Let us then proceed to ascertain whether there be any and what agreement between our principles and the phenomena to be presented to view; whether, in fine, our principles will endure the test of magnetic experiments, and consequently deserve to be considered as experimentally verified.

To ascertain this fact, we must first revert to the theory of elementary particles of which we have spoken in Chapters V. and IX., Part I., where we have drawn our conclusions with regard to the motion of their volumes, from the mechanism of the situation, motion, and figure of the parts; shewing,

1. *That the first and also the second elementary particles, or the magnetic, have the most perfect aptness and proneness to motion.* For, as we have there abundantly shewn, if in figure they be spherical, merely superficial, and having the resemblance as it were of a bubble; if also they be highly yielding and elastic; and if in every state of compression they be equally mobile and always similarly configurated; then must they have the greatest proneness and aptitude to motion, like elementary parts of all kinds: for every one of them has its own proper mobility; every one contributes its own little share to the general motion of the volume: every one in miniature resembles the whole volume, both as to figure and motion. For the elementary particles are parts of the volume, and parts of the motion, which are all active and passive in the same manner as the volume, and which have thus the same principle of acting and suffering themselves to be acted upon. Hence it is, that they have the most perfect aptitude and proneness to motion; and that *they spontaneously endeavour to enter into a vortical motion, if there be only an active centre round which they can gyrate.* For in every particle there is a force tending to gyration, and the forces in the volume are multiplied according to the number of the particles; there is hence a general effort in the volume,

because there is a particular effort in every part. These forces, as we have shewn in Part I., tend to a circular motion. In order therefore for them to pass into this motion, there is nothing wanting but an active centre; and all that this centre does is only to put them in motion; the very particles afterward dispose themselves into this motion and direct it;—a motion accordant with the force of each particle, namely, a vortical or gyratory motion round a centre.

2. *That in a volume of elementary parts all the motion is diffused and derived from a certain centre, where the origin of the motion exists, to all the parts round about; and to a greater or less distance according to the force of the centre, and the contiguity, elasticity, and yieldance of the parts.* For all the elementary parts are mobile of themselves; and inasmuch as they are contiguous, the motion is diffused and derived from one to the other, and indeed on all sides round about. Wherever there is anything contiguous, there also is the diffusion of motion: where contiguity ceases, the motion ceases. Undulation can proceed only as far as the limits of contiguity, nor can it extend farther. In the common elements we see a like contiguity everywhere presented; hence also in these we perceive their motion diffusing itself into all their parts, as in the case of undulations in water, tremors in the air, and modulations in the ether; which the ear and eye perceive in every periphery, and at every distance from the centre, provided the distance be not too great. The same contiguity exists in the volume of the elementary magnetic parts. If there be less of contiguity, there is a less dispersion and distribution of tremors and modulations. The motion may emanate from the centre to greater or less distances or circumferences, according to the elasticity or yieldance of the surfaces. For what is elastic returns to one adjacent particle the same force that it received from another: it restores itself to the space it occupied before impact: nor loses anything in either respect: whatever it receives, it communicates, but not at the same instant; for having first withdrawn itself into itself, it then expands itself within its own proper *moment*. The law of the diffusion of motion among elastic bodies is thus different from that which obtains between the particles of hard bodies in a state of fluency.

3. *But the motion between the elementary particles not only is propagated and extended according to the figure and natural situation of the parts, but it also terminates in them.* Inasmuch as among the elementary particles, every part, as we have before stated, contributes its share to the motion and figure of motion in the volume; it follows, that the volume of the particles cannot be moved, or configurate its motion, in any other manner than the individual parts allow. Hence the motion of the volume must be perfectly conformable to the motion and figure of the parts. If the elementary parts were exactly spherical, the motion would spread itself around into the form of a sphere, and describe perpetual circumferences equidistant from the centre. If the parts were not exactly but only partially spherical, then where they were spherical the motion would emane and diffuse itself in a like spherical manner; while wherever they were not spherical, they could not emane in a spherical form and spherically extend their figure of motion. For in the case of elementaries we may contemplate a volume in a particle, and a particle in a volume; we may deduce a general figure from a particular, and a particular from a general; so also may we with regard to a motion or a figure of motion. Thus the motion of elementaries in a volume is conformable to the figure, situation, and motion of the parts; according to the theory explained in Chapters V. and IX., Part I. And since the distribution of the motion in the volume is according to the figure and situation of the parts, the motion must finally terminate in the same situation with that of the parts, or in that situation in which the parts themselves are. These details being purely mechanical, follow by mechanical connexion and necessity.

4. *Hence we come to the conclusion, that the motion among the first elementary particles, and also the second or magnetic, is diffused in every direction from the centre to all the circumferences.* But inasmuch as the figure and situation of the parts is such, that the poles of all the particles, and also the equators, are all parallel, it follows that the motion among the particles is diffused in one way according to the poles, and in another according to the equators. For if the general motion be formed and effigied according to the figure and situation of the parts, it follows that it cannot diffuse itself among the elementary

magnetic particles from the centre to every angle with a like uniformity [*æquis passibus*]; that is to say, it cannot extend itself spherically into circumferences continually concentric or equally distant from the centre, but must move in a manner conformable to the figure and situation of the parts; in one manner according to the parallelism of the axes, in another according to the contact and parallelism of the equators; the axes and equators being the points and quarters that determine the direction of the general motion, and incline it more and more to the original figure, into which it is thus brought by mechanical necessity.

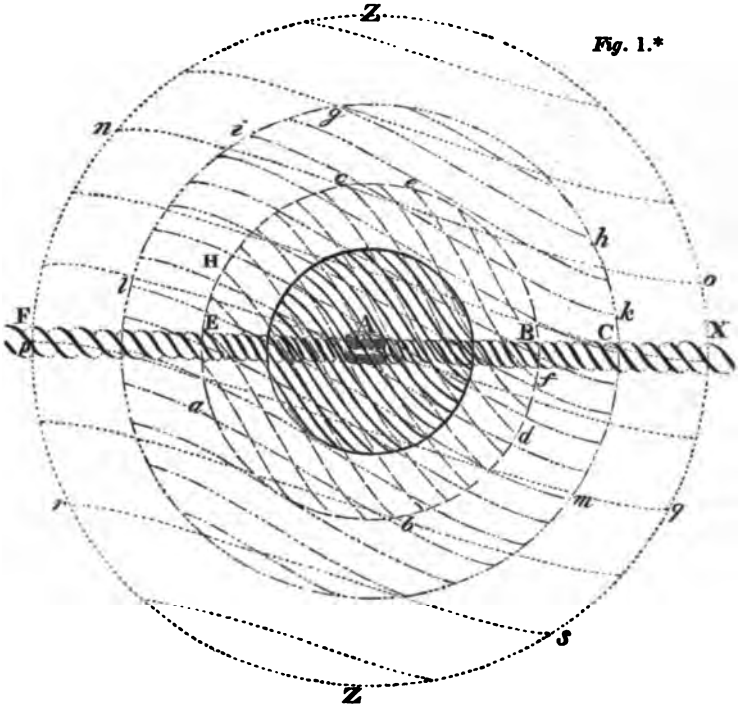
5. *Inasmuch as the diffusion and emanation of motion from the centre, is of one kind according to the plane or parallelism of the poles, and of another and different according to the plane and parallelism of the equators of the parts; it follows, that the motion cannot be diffused into circumferences equidistant from the centre, or similarly circular, but only into such as are spiral.* For if the motion according to the polar plane of the parts, be different from the one according to their equinoctial plane; and if this motion be nevertheless diffused from the centre to all the circumferences; it follows, that the motion diffuses itself more widely and quickly to one part than to another; that two motions are thus derived from one centre; and consequently that all the intermediate motions are proportional to these two, and cannot be extended or continued to any distance except in a spiral manner. A motion of this kind in a volume of parts is truly vortical; inasmuch as it propagates itself by spires to various distances, and thus spreads itself in every direction.

6. *In this spiral or vortical motion, the nearer the spires are to the centre, the greater is their curvature; the farther off they are, the less is their curvature; till it gradually ends in a right line, and thus in the situation of the elementary particles.* This follows from the former proposition. If the motion tend to the natural situation of the parts, in which it finally ceases; and if nevertheless it runs in circular directions from the place of its first beginning or centre, then it will at first form spires of greater curvature, and of less in proportion to its distance from the centre; till at length, instead of a spire, it will describe a right line conformable with the parallelism of the axis of each

part. For if the figure of motion becomes the more rectilinear according to the greater distance, and if it thus extends itself the more, in conformity with the situation of the parts; if also the figure be spiral or vortical; the spires will extend and unfold themselves more and more from a perpendicular and oblique into a right line. Imagine for a moment similar and larger particles moved one among the other, and all lying in a parallel situation: the motion cannot expand itself in any other manner than according to their situation in a longitudinal and latitudinal direction; and the figure of the spiral motion will be more and more extended, according to the axis: when the motion ends, it will end according as the parts lie. The like also is the figure of every part. The end of motion is rest: the situation of the parts is the state of their rest: the motion terminating in a state of rest must therefore be rectilinear.

In fine, all motion between the elementary particles, which we

Fig. 1.*



* In the original, plate III., fig. 37.

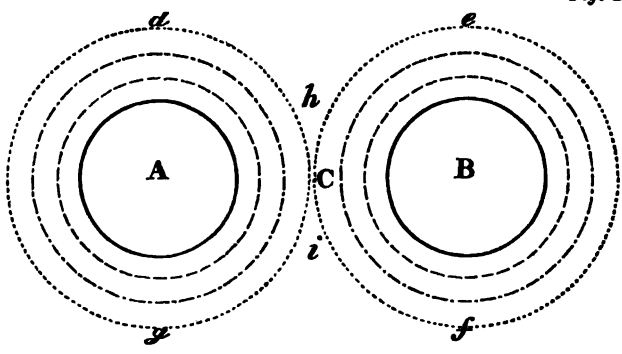
have called magnetic, runs round a centre in a spiral direction; and when it has arrived at its state of rest, comes into a rectilinear situation, and into the same with the situation of the parts at rest. In this consists all the magnetism treated of in the sequel. Let A be the centre of motion, round which the elementary particles are distributed. Let the distances from the centre be represented by circles, and in the present case by three. The spiral motion round the centre is of greater curvature nearer to the centre, as *fe, dc, b*H, and is evidently like the helix or spire in B, which we have drawn here only for the purpose of assisting the ideas of the reader. At a greater distance from the centre, the spires are of less curvature as *hg, ki, ml;* at a still greater distance, they have a still less curvature as *on, qp, sr;* and at a distance still greater, they have the least possible, or become rectilinear.

What we have here said of the motion of elementary particles, agrees with the principles laid down in the first part of this work; indeed, there is not the slightest difference between them. We have there affirmed, for instance, that the elementary particles are most highly elastic, yielding, and adapted to a vortical motion; that they are also most perfectly prone to this motion, purely from the action of a given centre spontaneously tending to this motion; that these particles cannot enter into any other motion than such as is consonant with the figure and situation of the parts; that the only motion conformable to this figure and situation is the spiral; which ultimately, according to the situation of the parts, passes into the rectilinear; that the curve of circulation is consequently greater near the centre and less proportionably to its distance from the centre; the consequence of which is that a vortex is formed. Nor must we omit to mention, that the motion which is according to the axis of each part is more indocile, resisting, and (so to speak) harder than the motion which is distributed according to the equator of each. At the equators the particles, according to their mechanism, appear to be the most highly yielding; and, at their contact there, are most highly elastic and sensible, but not so at their contact at the poles. Hence arises the difference between the motions; hence the spiral figure; as also the termination of the motion in a right line. A sufficient reason

for these things, however, may be found in the mechanism of the figure itself, as described in our foregoing remarks.

7. These spiral gyrations which arise from a certain active centre, we may, in the sequel, denominate vorticles; and every gyration from its own proper centre, a single vorticle; for the motion is entirely and truly vortical from the centre to the circumferences. From the connexion between our principles it follows further, that *there may be as many spiral gyrations or vorticles as there are centres of motion; and that the vorticles may be conjoined one with another in a manner conformable to their figure and motion.* For if there be several centres of motion, then will there be several spirations, spiral gyrations, or vorticles. For the particles are so ready and prone to this motion, that they have no need of anything but centres, at which the motion may begin, and round which, when begun, it may flow. When a centre is given, then a gyration takes place round the centre. If there are several centres, then there are several vorticles adjacent to each another; one within, another without, the sphere of the other. Just as is the case with undulations in water, one of which follows close to the other, provided only the volume be put in motion from a centre; also with tremors and vibrations in the air, in which case one follows close to the other, provided only the air be disturbed by some vibrating force at a given centre. We may see a like illustration in modifications of the ether, the centres of which may exist within as well as without the sphere of any other modifi-

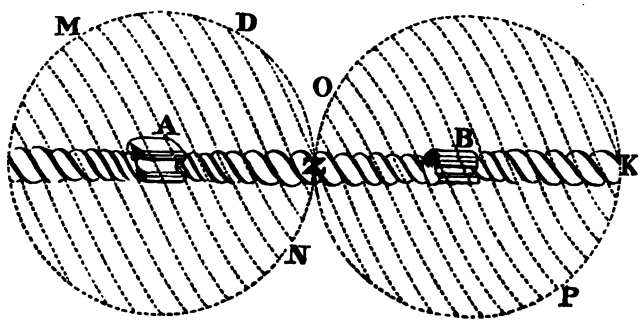
Fig. 2.*



* In the original, plate IV., fig. 42.

cation, or modulation. Thus A and B are two centres, from which the motion propagated is represented by circles. If by the intervening circles these centres are conjoined at C, then the circles *ef* and *dg* may mutually extend themselves so as to form the sphere of another circle; and so that, as far as regards motion, the sphere of one may enter into the sphere of the other. The case is the same also in the exquisitely subtile elements of which we are treating. Gyrations or vorticles may travel from various centres, either without or within the sphere of another. Nature is always most perfectly similar to herself, especially in the elements. Since therefore there may be as many vorticles as there are centres of motion; and since one may be near to another; it is to be observed, that vorticles cannot possibly be conjoined one with the other unless in a manner conformable to their figure and motion; and unless the gyration of one be conformable to that of the other, the motion of one to the motion of the other; and unless also the spires of each vorticle be concordant with each other, as to their mechanism; so that the plane of the motion of one may accord with the plane of the motion of the other, and the current of the one with the current of the other, that is to say, so that they may be conjoined in the current of their spires. In Fig. 3 we

Fig. 3.*

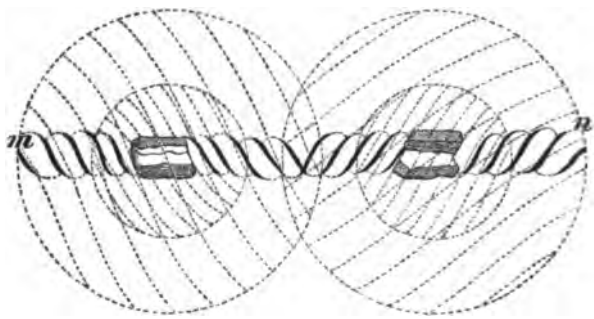


see two vorticles of the same kind, the centres of which are A and B; the spiral motion of each is in a direction from O toward P, or from M toward N; if the currents of the spires, or the planes, be in the same parallelism, this is the state in

* In the original, plate III., fig. 38.

which the motion of each is capable of being the best conjoined; and one vorticle may continue its gyration near another without any resistance or retardation. If therefore the vorticles are to be reciprocally conjoined, this conjunction must take place in the current and flexure of the spires. Thus if we wanted two pullies or two worms [*helices*] continually to act together, the obliquity of their planes must be in accordance one with the other; in which case only can the two be properly conjoined; were the relative position of each, and their mode of conjunction, contrary the one to the other, the result would be a conflicting motion between the two; and from two contrary motions, would arise a certain quiescence of the parts or else an extinction of the motions. Thus in Fig. 4, the circles of one vorticle run crosswise

Fig. 4.*



to those of the other; and in a motion of this kind the current of one opposes the current of the other; hence they tend mutually to stop each other, and to bring one another into a state of rest. We see then the manner of conjunction of these vorticles; a conjunction which is mechanically the closest possible, when the current of one corresponds with the current of the other, and when the plane of motion of one has the same obliquity with the plane of motion of the other. Moreover as the figure and situation of the parts is the same with the figure and situation of the compound or volume, in the elements; so, according to the general rule laid down in our first principles, it follows, that the conjunction of the volumes vortically moved, or of the vorticles, will be similar to the conjunction of the parts, which

* In the original, plate IV., fig. 44.

are conjoined with each other only at the poles; so that there is thus a parallelism of axes, and a harmony of motions.

8. *If the vorticles are conjoined as to their spires, and as to the harmony of their motions, they are also as it were mutually colligated by their conjunctions; and tend to remain in that state of conjunction.* For they do not easily suffer themselves to be inflected into any other situation; since the spire and motion of one has most agreeably, naturally, and mechanically, entered into the spire and motion of the other. Thus do the vorticles, in consequence of being closely fastened one into the other by their concordant motion, cohere as it were: were they reduced by any force into any other situation, their very plane and power [*potentia*] of motion would oppose the change, and forbid the disjunction of the two; thus do they remain conjoined in their own natural situation, from which they cannot be displaced except by force. If there were innumerable spires formed by motion, and mutually attached to each other, the motion would scarcely permit of their being dissociated, and the difficulty would be the greater the more intense was the motion, and the greater the curvature of the spires. Everything which is contrary to the mechanism, is contrary also to the force, conjunction, and potency of the parts. Hence when two vorticles of the same kind are not conjoined in one oblique plane, or one spire of motion, but in many and innumerable, they cannot be dissolved and dissociated except by some kind of extension of their motion; by some change of their state or some force proportioned to the motion and the plane. Hence these vorticles being harmonically and mechanically conjoined in their motions, have a permanent union, and powerfully oppose, upon mechanical principles, any change in their situation.

9. *Vorticles, or spiral gyrations of this kind, have a greater tendency to conjunction and colligation with each other the nearer they are to the centre, or the greater the curvature of the spires by which they are conjoined.* As spires which are nearer to the centres have a greater curvature than those which are more remote, so are they more strongly colligated if they coalesce with a greater curvature, than with a less; consequently they unite with each other the more strongly, if they are nearer to the centre, than they would if they were more remote. The

motions of a spire are of greater curvature at the centre of motion; of a less at a farther distance; while at a distance still farther the fluxion almost ceases to be spiral, and becomes nearly rectilinear; consequently there is no colligation between the two. Besides the nearer that gyrations are to their centres, the more incurvated and the more numerous are the spires by which they are conjoined, or the circles inflected into a spiral motion; the conjunction being secured, so to speak, by chains wound the more frequently round them.

Hence we infer, that *the closest colligation of motion is nearest to the centre; because there the gyration has the greatest curvature; in the intermediate distance, the degree of colligation is intermediate; at the farthest distance there is none; inasmuch as the gyratory motion there begins to be determined into a right line.* Moreover, *colligation exists wherever the angle of the spire is less than forty-five degrees.* It follows also, that *the more numerous are the centres of motion in the same plane, the greater also is the gyration and colligation of the vorticles; the fewer in the same plane, the less is the colligation;* also that *there are as many colligations as there are centres of motion;* not to mention other particulars, which, as they necessarily result from the same mechanism, do not require any special notice.

10. *Corpuscles consisting of pores and meatuses so subtile as to be permeable only by magnetic elementary particles, are magnetic corpuscles; especially if the pores or meatuses are rectilinear.* In hard bodies there are corpuscles diversely configurated, as also diversely perforated: there are pores which are more open and larger; pores also which are smaller, according to the nature of the compositions, of which we shall have to treat in our theory of the mineral kingdom. I hold however that corpuscles of every form are magnetic; provided the elementary magnetic particles can pass through their pores, and connectives of their structure [*nexus*], and do not open wide enough for particles of a grosser element. Of this kind are the smallest corpuscles or effluvia proceeding from magnets and iron; as will be evident in the sequel, from the phenomena which will be adduced. The magnetic substance itself is ferreous, and is found in all parts of the world. Iron is a mineral the most common, and the most universal in the mineral kingdom. Almost all kinds

of soil are pregnant with particles of iron, as experience testifies: the very ground itself is full of them. Rivers, fountains, and lakes are often heavy with iron [*marti*] and abounds with its vitriol; as is evident from their sediments and impurities. Vegetables themselves are also pregnant with iron, as is evident from their ashes; in fine, the mineral most generally prevalent upon our earth is iron: it is therefore no wonder that in iron, the pores of the smallest parts or of the effluvia, are formed in accordance with the situation of the elementary particles. The situation of the particles of this element is itself, according to the principles we have laid down, rectilinear; and if these particles are superincumbent upon the surface of the earth, and are present at the formation of this very prevalent metal, it is no wonder that its ducts and extremely minute sinuses should be fashioned in accordance with the situation of these particles and be consequently rectilinear. For the most subtile elementary particles continually enter into and penetrate the contexture of the harder bodies; and by their perpetual flux and reflux create for themselves in the course of their permeations passages perfectly similar; that is to say, rectilinear. From these circumstances merely it might be concluded, that there are corpuscles of this kind so small as to emanate and exhale from hard bodies in the form of effluvia; and that these corpuscles are penetrated and rendered pervious only by the most subtile elementary parts; and this too in the direction of a right line, or conformably to the situation of the particles of the element. Were the minute foramina above mentioned not rectilinear but inflected at various angles, they could not possibly be magnetic; as we shall see in the sequel.

11. *Corpuscles of this kind, or effluvia, when free, cannot be quiescent; but gyrate continually round their centre, conformably to the situation of the elementary particles.* They constitute therefore active centres, and form around themselves spiral gyrations or vorticles. If now the porules occupied by the effluvia are crowded, and filled only with magnetic particles, these particles cannot possibly be quiescent; for the other elementary particles they enclose have themselves a perpetual axillary motion, as we mentioned in our theory of these particles; and consequently, together with these, the corpuscles or effluvia whose in-

terior texture and sinuses they alone fill and as it were distend. For the elementary particles are both active and passive, since they partake of both principles; they are apt and ready to motion; consequently if the magnetic corpuscle be free, they induce it into an axillary motion. And even if the enclosed elementary particles do not act, still there are others which touch and press the surface of the corpuscle, and put it into this motion; and if by any internal or external cause they are put into a gyratory motion, it must be a motion which is conformable to the situation of the elementary particles occupying their interiors and exteriors. The elementary particles which are within, flow in connectedness with those which are without; nor can they, by reason of this connectedness, circulate in any other way than in a species of rotation, or with a common motion; that is to say, with an axillary motion similar to the axillary motion and situation of the elementary parts. So that in the very smallest element or individual part of a magnet, there is a polar situation and relation. Thus in Fig. 5 and 6 the magnetic bodies are re-

Fig. 5.*

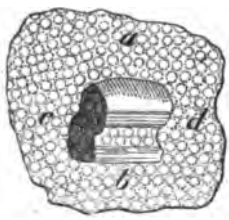
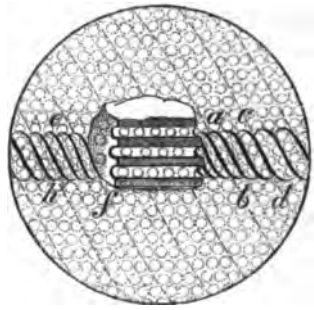


Fig 6.†



presented as opening on each side with rectilinear pores; the magnetic particles as occupying their interior texture or sinus, and in like manner as flowing externally; and inasmuch as the interior and exterior are so connected, the effluvium itself is under the necessity of being driven round the axis which the enclosed elementary particles occupy and form. In case, however, the pores were not rectilinear, but variously incurvated and inflected; in case moreover they were unequally and irregularly acted upon, no axis would be formed, nor would there be any general consent

* In the original, plate III., fig. 36. † In the original, plate III., fig. 42.

to an axillary motion; but one part would endeavour to gyrate [*volvere*] its corpuscle at its own situation and angle, another, to do so at the situation and angle proper to itself; and consequently all of them collectively to do the same either at an uncertain and doubtful angle, or at no angle at all. A rectilinear situation or channel of the pores is therefore requisite.

12. *Accordingly, such as is the number of magnetic effluvia, such is the number of vorticles formed round the magnet;* one or more will be within or without the sphere of another or neighbouring vorticle.

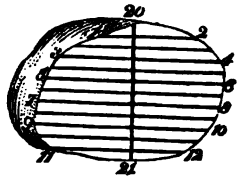
13. *The greater the quantity of this effluvia round a magnet, the greater is the number of centres and vorticles; also the more nearly and closely may they be conjoined and colligated by their interior spires; and* vice versâ. Inasmuch as the centres may be active to a considerable distance from themselves, and one may gyrate near another in its very vorticle, and circumflect itself into a spiral figure, it follows that the more centres there are, the nearer are the vorticles in contact with each other, and with the more interior, more incurvated, and more colligating spires do they conjoin themselves, as we have previously shewn.

14. *The natural place of the effluvia is in the centre of this vorticle; nor can the effluvium, residing and acting in its centre, eject itself out of the vorticle; for it is inseparable from the vorticle, and is naturally carried in the direction in which the vorticle moves, and* vice versâ. For if the spiral gyration or vorticle arise from a certain centre, then the vorticle without its centre is nothing; if the centre be wanting, the gyration is wanting; hence wherever there is a centre, there is also a gyration: the centre is thus inseparable from its circumferences: the vorticle circumferences, with the centre, constitute one motion: the centre therefore follows its own motion, and the motion follows its own centre; nor can the centre eject or convey itself out of the vorticle; for this would be to separate one and the same thing from itself; in other words, to annihilate it.

15. *If within any hard or material body there be effluvia, or smallest parts of this kind, both free and colligated, but extending in a right line or in a regular curve from one side to the other, or from one pole to the other; then, I hold, that such a hard or*

material body is wholly magnetical. For instance, if the mass, or mineral, or hard body, be one through which effluvia of this kind not only flow, but into whose composition they enter, then this body possesses a magnetic force; provided the situation of the effluvia be in a right line or a regular curve extending from one extremity to the other: since the vorticles colligate themselves by inmost spires and circles, not only with the body (thus connecting as it were one side of the body with the other,) but also with the effluvia of the same kind which flow externally to it, or which are in its confines; and thus it is that the whole body, from one pole to the other, together with the entire sphere of vorticles which flow without, presents itself as magnetical. If the effluvia filling the hard body were not conjoined in a right line, but occupied such a position as to be everywhere at an uncertain angle, they would also conjoin themselves at sundry different angles with the circumfluent effluvia, and would form with them irregular connexions; so that one vorticle could not adapt itself to the spires or current of the other; one could not enter into the motion of the other; the vorticles would not conjoin and colligate themselves in any series, according to parallel planes, but one would interfere with the free action of the other, by crossing it at one time obliquely, at another at right angles, and at another by moving in an entirely opposite direction: thus would one not only disturb the circles of the other, but extinguish and annihilate them; consequently the situation of these pores within the compages of the mass ought to be rectilinear or regular; as in Fig. 7, where all the ducts lead in rectilinear and parallel directions from one side to the other, as in the case of those marked 1, 2; 3, 4; 5, 6; 7, 8; &c.

*Fig. 7.**



16. *The more regular the situation of the corpuscles, and the greater their quantity both within and without the mass, the closer is their conjunction and the stronger the magnetism.* For magnetism itself consists in the union of the vorticles within and without the mass and in the confines between the two. The more regular the situation of the parts within the mass and in

* In the original, plate III., fig. 41.

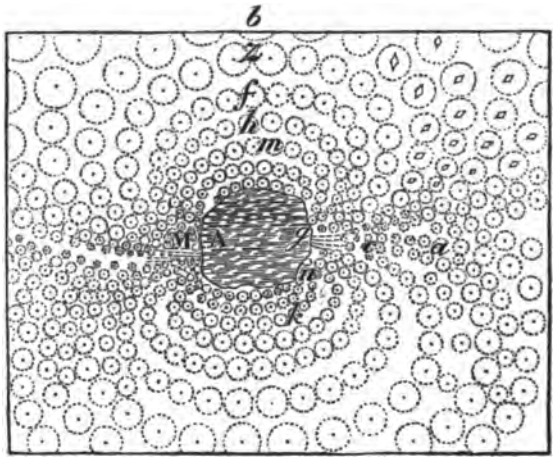
its confines, the more regular is the situation and conjunction of the vorticles without the mass. Thus one is colligated with another in a continuous series; and all are disposed together more conveniently into one sphere; a contiguous extense is formed round about from one pole to the other, and vorticles in connexion one with the other everywhere enclose the mass, bracing it round as it were and tying it close to themselves. If however the situation of the emaning effluvia be irregular, then a discord and disjunction of the motions are the consequence; and the magnetism ceases with the cessation of the connexion and contiguity of the parts.

17. *The colligation of the effluvia or vorticles is closer at a less than at a greater distance from the mass; and closest at its confines or boundaries, or nearest to the mass.* Near the point of exit or in the very wall [*paries*] of the mass, whence the effluvia are exhaling, and whence they diffuse their particles conjunctively throughout the sphere from one pole to another, or from one wall to another, there must necessarily be in a given space a larger quantity of effluvia; and consequently at this place the vorticles reciprocally embrace each other with their spires the more closely; while at a distance from this point, where they have more room for flying abroad, the vorticles are rarer and consequently are held in conjunction by spires of less curvature; having a more feeble potency, and a duller force: therefore the nearer they are to the polar wall, the closer is the bond of connexion, because the greater is the quantity of them in a given space.

18. *The vorticles surround this mass by a continually connected link from one polar wall to another; and thus connect and enclose each wall and pole by means of a kind of sphere.* For not only do the effluvia exhale from each wall of the magnet, but also immediately connect and colligate themselves with the circumfluous effluvia: thus do the two conjoin themselves one with the other, and extend from one polar wall to the other. Inasmuch also as the magnet is surrounded with effluvia both at the polar walls and at the equinoctial, that is, both above and below, both directly and obliquely, the vorticles of these effluvia necessarily coalesce, by a similar fluxion of all, into one sphere; but this can be done mechanically only from pole to pole by a

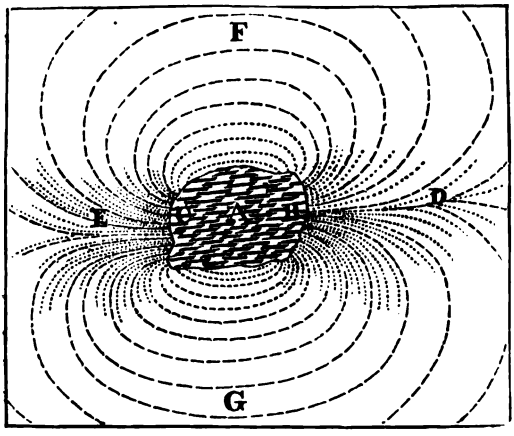
regular incurvation and figure, as in Fig. 8, in which *g* is one

Fig. 8.*



polar wall where the circumfluous vorticles first consociate and conjoin themselves, with those which press and as it were lie upon [*insident*] the mass: A is the other polar wall, where, in like manner, the circumfluous effluvia are colligated with those which contiguously press upon the wall, and these cannot but be united into one sphere, from one pole to the other, as we may see also in Fig. 9. *By this sphere therefore is formed a*

† *Fig.* 9.



* In the original, plate III., fig. 39. † In the original, plate III., fig. 40.

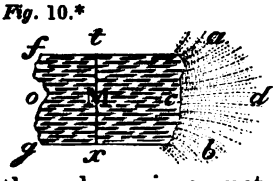
figure similar to the oval, conformably to whose curvature or surface the axes of the vorticles are inflected. For if the centre in the middle be active, and if the fluxion of the surrounding elementary particles be spiral, and if there be several or innumerable vorticles of this kind near one another; then will one vorticle adapt itself to the other; the motion of one will direct and turn that of the other; and will adjust the obliquity of the neighbouring vorticles, together with the effluvium itself, to the plane and angle of its own current. Thus will it incurvate the axis of motion belonging to these, so as to adapt it to the axis of its own motion. The harmony and conjunction of all consist in the similarity of the streams of motion, and in the reciprocal application of one to the other. Hence, without any lesion of the motions and fluent spires, either the effluvium and with it the vorticle, or else the axis itself of the vorticle, may be inflected obliquely and consequently into any curve.

From what has been said it also follows, that *the sphere of the vorticles thus connected may endure for a considerable time round the whole magnet: nor is there any need for it to be constantly renovated with fresh effluvia; also that no great quantity of these continually exhaling effluvia is required. It follows likewise, that the magnet itself* [lapidem], *surrounded with such a sphere of vorticles, cannot possibly be removed from one place to another, without removing the whole sphere together with it; that the sphere itself cannot be removed from one place to another without removing the magnet together with it; that the magnet and sphere constitute as it were one body; and that one cannot be separated from the other, much less be translated out of the other, but that the magnet in the centre of its sphere (in whatever situation and motion) naturally and always accompanies the sphere, and the sphere the magnet.* With regard to our last position, namely, that the magnet always accompanies the sphere, and the sphere the magnet, this is evident from what has been said above; for since the vorticles at a distance from the magnet are perpetually and reciprocally tied and colligated to each other, and those which are nearer the mass more closely than those which are more remote; since there is thus a connexion between them all and the mass itself; it follows that one depends from the other by contiguous connexion, like one continued series and concate-

nation; so that there can be no magnet unaccompanied by a sphere, nor any sphere unaccompanied by a magnet; and that, as is evident from Fig. 8, there is a continual connexion between them extending round about to a considerable distance; nor can one vorticle remove out of its place, and be withdrawn from a connexion with the adjacent, unless the adjacent and proximate vorticles themselves are removed and withdrawn, or undergo some mutation; and this even up to the magnet itself, where the colligation is the closest: so that the magnet itself, thus conjoined with these vorticles by contiguity, or by a continuous connexion of the spiral motions with every part of the sphere with which it is surrounded, is rendered subject and obsequious to every change of the sphere.

19. *By reason of the connexion between the vorticles which extend from one pole to another, and of the formation of the sphere, there exist poles one on each side of the magnet: there exist in like manner polar axes extending in the sphere to a distance from the magnet; and these axes do not receive their determination from the magnet, but from the sphere and its figure.* That not the magnet but the sphere forms the polar axis on each side, is evident from this circumstance; that the polar plane passes through the whole magnet from one side to the other; as in Fig. 10,

Fig. 10.*

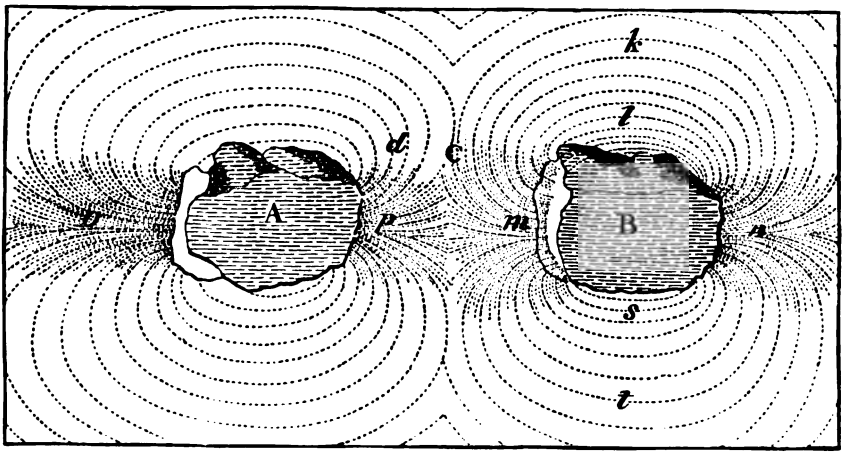


where the whole side *fog* is polar, as also the opposite side *acb*, and the elements of the effluvia travel within the mass rectilinearly from *fog* to *acb* according to the interior texture. Hence the polar axis cannot have any fixed place in the magnet, but the place and situation of the poles are owing entirely to the sphere, which is compelled to encircle the magnet according to the figure of the latter; thus sometimes in one way, sometimes in another. The sphere itself, which extends from one wall to another and consequently bends itself round by a certain curvature, forms a pole or polar axis in the place where the vorticles begin to incurvate their course. Hence all the vorticles which are colligated together proceed at first according to this axis, in a right line from the magnet; and then deflect themselves

* In the original, plate III., fig. 41.

from the axis, in every direction, into a curve. This we may see in Figs. 8 and 9 (p. 228), and also in Fig. 11.

Fig. 11.*



20. *The axes of the vorticles are not in one parallelism and situation with the axis of the sphere; but are incurvated according to the figure of the sphere; and this incurvation begins at the polar axis of the sphere.* For the vorticles diffuse themselves round the magnet in a connected series from one pole to the other; the motion and spire of one applying itself to the motion and spire of the other, until from one pole, by their continual flexure and mutual application, they reach the other pole; and by the application of their motions and their situation thence arising, thus colligate both the poles, or enclose the magnet, so colligated on both sides, by one continued gyration. And since the motions of the vorticles are thus mutually inserted into each other, it necessarily follows that their axes also must mutually become applied to each other and incurvate themselves. Hence the axes of the vorticles and the axis of the sphere are not parallel; as will be seen more clearly illustrated in the figures.

21. *The axes of the vorticles and the axes of the elementary particles round the magnet are in the same parallelism; and the elementary particles are disposed by the motion of the vorticles into the same situation, and the same figure of situation with the sphere;* as will be shewn in the sequel.

* In the original, plate IV., fig. 43.

22. *The whole motion in the vortice is according to the situation of its axis; or the axis has a flexure conformable to the motion. If the axes are in a right line the motions in the vortice are concentric; if the axes are incurvated, the motions are eccentric; if several vortices are in the vicinity of each other according to whose motion and application the axes are to be curved, then is there at different distances from the centre or effluvium a different eccentricity.* This is observable likewise in the large vortex of the sun, where the planets describe ellipses round their centre or sun, and in one focus of which the sun is situated; the cause of which we shall here briefly explain, as we are now treating of the vortical motion. For the magnetic sphere with its vortices is a type and small effigy of the starry heaven; there is the same kind [*ratio*] of motion in small things as in great; because in both the element which has a vortical motion is the same. We are to observe, that the situation of all the elementary particles round the magnet is according to the figure of the sphere; and not only that there are vortices which thus circumflect themselves from one axis to another, but that together with the vortices the particles of the element are likewise inflected; so that the elementary particles themselves are so connected as to their poles as collectively to form this figure. Thus in Fig. 11 all the dotted lines are not only effluvia with their vortices, but they are also the elementary particles themselves brought into a like situation; so that the magnetic sphere is to be conceived as consisting of elementary particles, inflected into the same situation as that in which the points flow in the figure. For the motions and fluent spires of the vortices, which by their mutual application bring each other into this situation, dispose and draw the elementary particles into the same situation: in fine, the situation of the elementary particles is the same with the situation of the vortices. If the elementary particles be conceived to be in this situation; and the effluvia or active centres between them to be disposed into this order and figure; in this case I observe, that all the spiral or vortical gyrations arising from the centre, apply themselves to the situation of the particles. And if the axes of the vortices are parallel, or the same with the situation of the elementary particles in this magnetic sphere, it follows that in some places the axes

are rectilinear, in others curvilinear, and more or less inflected. If the axes are inflected and curvilinear, then the vortical motion thence arising is not concentrical or circular, but eccentric and elliptical; in one focus of which is the effluvium, whose distance from the centre of the ellipsis is proportioned to the curvature of the axis; for the vortical or spiral motion emanates in all directions from the centre or effluvium, and more and more unfolds and extends itself into a parallel line with the axes; that is to say, ceases to be in a state of accordance with the situation of the axes. If therefore the axes are incurvated, the spiral motion runs from the centres to the equators of the particles to a greater distance on one side than on the other; inasmuch as the situation of the particles urges the motion in that direction; and consequently by the motion spiral circles are formed, which in respect to the effluvia are not concentric but eccentric and elliptical. For were the axis not inflected in one but in different manners, in consequence of the approximation or vicinity of several vorticles, then would various ellipses be described by this spiral motion, at various distances from the effluvium; none of which would refer to one common centre; as is plainly the case with the ellipses described by the planets in the solar vortex. It is to be observed, that the axis of the vorticle is equal to its entire latitude: it is not formed by only a brief fluxion from its centre, but extends throughout the whole of the breadth occupied by the vortical motion, as in Fig. 1 (p. 216), where a vorticle is represented of a circular form. In this case its axis is not to be conceived as equal to BCX only, or to AEF only, but as equal to the whole breadth from X to F or from Z to Z. For all the elementary particles among which the vortical motion exists, are in this situation parallel to each other. Hence an axis of this kind, and of such a size, may be inflected by the motion of the neighbouring vorticles in different ways; and consequently the motion may form various ellipses at various distances from the centre, or ellipses of different eccentricities. On this subject, however, I shall speak in the theory of the vortices and the planets.

23. *The axis of the sphere, or the common axis of the vorticles, lies parallel with the common axis of the element itself, so as to be exactly accommodated to it; but nevertheless it may be easily*

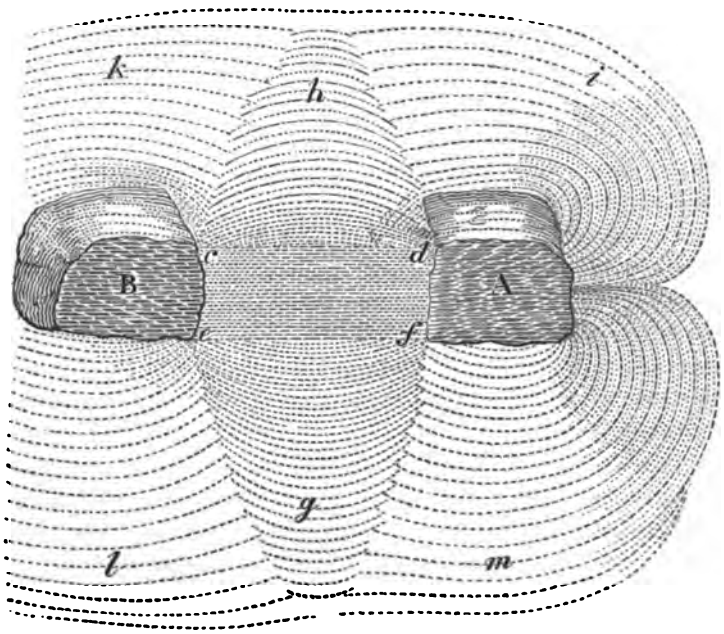
diverted from this into any other direction. By a sphere we understand the entire compages and series of vorticles connected into the figure extending round the magnet. Inasmuch as the motion of all the vorticles has its termination and ceases in the general situation of the particles or of the axis, it will consequently, if free, always be directed and relapse into this situation from the common one.

24. *The axis of the whole sphere, or the common axis of the vorticles, may be incurvated in like manner; and together with it, the sphere itself may also, from one pole to another, undergo any change; or what amounts to the same, the sphere itself may from one pole to another undergo a change and be incurvated according to the polar axis.* For if the sphere form an axis according to its figure, then if the figure of the sphere be changed, the axis also is changed or incurvated, and *vice versâ.* For the axis derives its origin from the sphere; and where the vorticles begin to incurvate themselves around the magnet, there is the axis; if therefore another figure or situation of vorticles arise, there exists also another situation of the axis.

25. *By the application of two or more magnetic spheres, the figure of each is immediately changed: from two or more spheres arises one that is larger; and the whole of the distance between the spheres becomes an axis.* For vorticles, if applied to vorticles, coalesce, as it were, into one volume: the motion of one immediately enters into the motion of the other; and thus arises a conjunction and ligation of the vorticles; for one vorticle is conjoined as to its current and motion with those of the other; if they do not coalesce, a renitency and collision arise; for there is no equilibrium without a conjunction and harmony of motions. Unless there were this mutual agreement among the vorticles, they would fly off in all directions, and the sphere would be dissipated; hence they naturally unite together and connect themselves into a similar situation; and this, upon those mechanical principles which we have frequently demonstrated. Homogeneous motions do not accord with heterogeneous; nor like with unlike; neither do two contrary motions which are unable to form any equilibrium or mutual connection; there must be a mutual application of their fluent spires. This we see illustrated in the case of fluids of every kind; in

which, by approximation or contact, the volume of one commingles or confounds itself with that of the other; a volume of water with water; a volume of air with air, of fire with fire, and of mercury with mercury; in a word, any one fluid with a volume of the same kind. More particularly does a sphere itself, or volume of vorticles flowing round the magnet, coalesce with an approximating new sphere; for the motion of each is subjected to no disjunction, or discordancy of situation; consequently from two or more vorticles there arises one: as in Fig. 12, where A and B are two magnets with their spheres,

Fig. 12.*

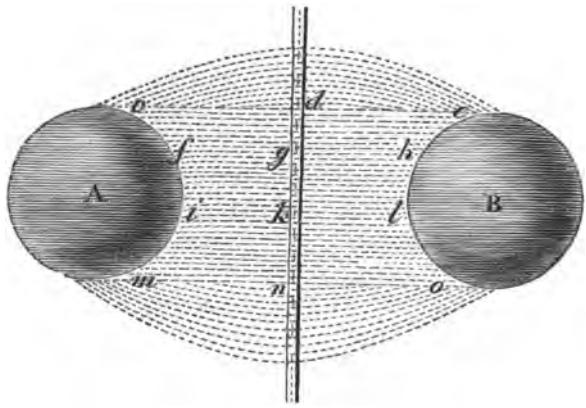


the spheres becoming attached one to another, as also the vorticles in respect to their motion; and in the union and similarity of their motions they seek and acquire equilibrium: hence arises a conjunction of all the motions between the two magnets; while the axis from being narrow becomes wide and broad, equalling in width the whole width of the magnet, as in

* In the original, plate V., fig. 1.

Fig. 13, where *cde,mno,* represents a broad axis between two

Fig. 13.*



spherical magnets or *terrellæ,* as they are called, and A B its middle; the vorticles, or sphere of vorticles, incurvate themselves round each magnet from this broad axis as they do from a narrow one, and enclose it within one figure or sphere. The spheres may however be attached to each other in different manners; as for instance at the poles, or the axes, or at the equators; also obliquely and intermediately; the sphere of one magnet in a different manner from the sphere of another. And inasmuch as the situation of the vorticles is diverse, and also the figure of the sphere, there may exist innumerable species of applications, and hence innumerable species and diversities of figures and conjunctions; and consequently diverse forces and powers. Hence *according to the different application of the spheres, is the larger sphere thence arising differently configurated.*

26. *Two or more spheres mutually applied to each other, are colligated more closely at a smaller than at a greater distance.* For if the vorticles nearest to the magnet are in the closest conjunction and in a spiral and mechanical ligation; and those are in a less conjunction which are more remote; then the two spheres are colligated more closely at a smaller than at a greater distance from the magnet; as in Fig. 14 and 15, where A and B are two magnets, and the intermediate vorticles extending along

* In the original, plate V., fig. 7.

the distance *ihagf* are variously conjoined; some with spires more intimate, curved, and rapid, which are those nearest to the mag-

Fig. 14.*

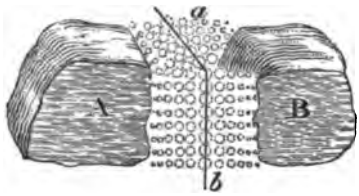
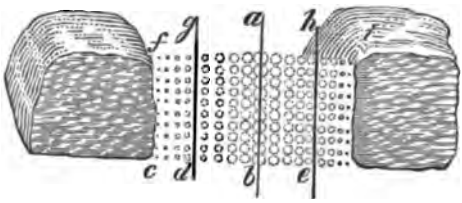
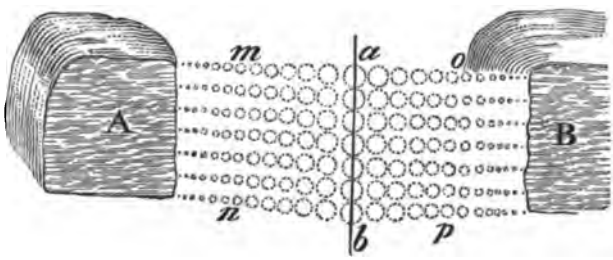


Fig. 15.†



net; others with spires less curved and rapid, which are those farther off from the magnet; as for instance, the vorticles in *he* or *gd* which are more closely colligated; because we not only find here a larger abundance of them, but they are more nearly conjoined with those which are in [*insident*] the magnetic wall; while in *ab* there is a less abundance of vorticles, and they are consequently conjoined with each other more loosely, and with spires of less curvature. If therefore the magnets are brought still more closely to each other, as in Fig. 14, the spheres touch each other with spires that are closer one to the other, and more

Fig. 16.‡



* In the original, plate V., fig. 3. † In the original, plate V., fig. 2.
‡ In the original, plate V., fig. 4.

connective; they are consequently more strongly united. The same things may be seen illustrated in Figs. 16, 17, 18, where different distances are given, or where the magnets or their spheres are unequal.

Fig. 17.*

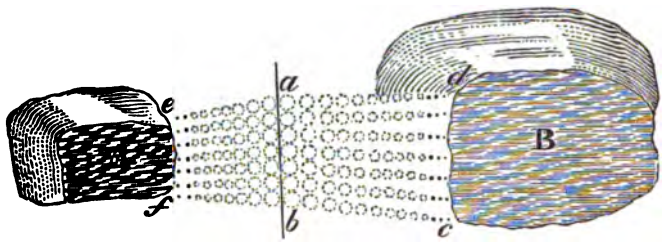
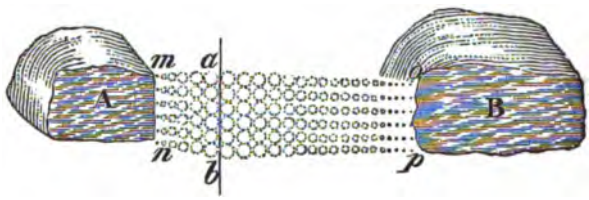


Fig. 18.†



27. *The conjunction of the spheres is the most close and direct at the poles; but between the poles is slighter and oblique;* for at the poles the situation of the vorticles is rectilinear, but at every distance from the axis it is oblique; in which oblique situation they nevertheless all refer themselves to the axis, upon which depends their union with the magnet. For the whole sphere is concatenated, as by links, with the vorticles of the axes: if the vorticles out of the axis are moved from their own place to another, then in consequence of their all being in series and connexion, the vorticles [*insidentes*] in the axis are also moved out of their place and drawn along with them; consequently also, by their connexion, those which are immediately conjoined with the magnet. Thus not only the motion, but the ligation also is of the whole sphere with the axis, and of the axis with the magnet; consequently the direct conjunction at the axis is the strongest and most close.

* In the original, plate V., fig. 5. † In the original, plate V., fig. 6.

28. *The greatest part of the effluvia of iron or steel is magnetic; but in consequence of the irregular situation of the parts in iron or steel, there is no regular conjunction of the effluvia or vorticles; consequently no sphere is formed by any regular situation of the parts; nor can any magnetism be produced, before the vorticles with their effluvia interiorly in the iron or steel, are reduced and disposed into a regular situation.* That the magnetic effluvia are purely iron, penetrated and perforated at its formation by the magnetic element, we have already observed (Art. 10): hence in the magnet there is nothing magnetical which is not iron, and there is nothing truly iron which is not magnetical. Hence there is a larger quantity of this effluvia surrounding iron, than surrounding the magnet. But inasmuch as magnetism consists in a perfectly regular situation of the parts, and a perfectly regular figure, into which the effluvia with its vorticles are disposed, the iron possesses no magnetic force, unless at the same time it possesses a regular situation and figure of its smallest parts. For when subjected to the melting heat of the furnace, or to the different changes attending refrigeration, or to the frequent tremors and vibrations received from the hammer upon the anvil, the smallest parts are brought into an irregular situation: and the consequence is, that there is no regular connexion between the parts in the interior texture of the iron, nor any in its wall and superficial terminations; and consequently none with any circumfluent sphere; hence there are no poles, no equators, no relation of vorticles, sphere or figure to an axis; nor of this axis to the iron: in fine, none of the parts conspire to produce any regularity: hence the iron being surrounded by discordant situations of effluvia, is rendered void of all magnetic power, inasmuch as the effluvia do not possess, in virtue of an axis, any conjunction with the body or mass. If however the effluvia with its vorticles be, from any cause, disposed into a regular situation interiorly in the compages of the iron, so that a regular conjunction be produced at its boundary and a disposition into a regular figure, in this case the iron is immediately invested with a conjunctive and magnetic power. On the figure of the sphere surrounding the iron, the reader is referred to Chap. XII. of this Part.

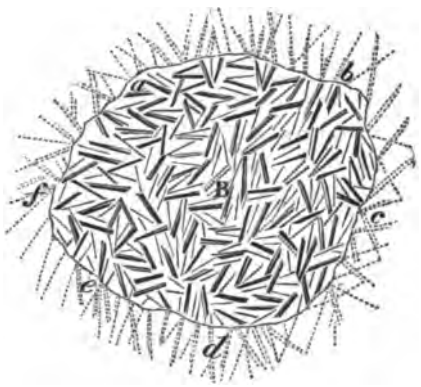
29. *If the effluvia of the iron approach the effluvia of the*

magnet, or the sphere of one approach the sphere of the other, each sphere coalesces and unites into one that is larger; and the whole distance becomes an axis: the magnetism is thus rendered more powerful; as is evident from the causes alleged in Art. 25. For two spheres by the approximation of their vorticles and the application of their motions, combine into one, and extend themselves, like an axis, from one of the bodies, from which they are exhaling, to the other; or, by means of a common axis, conjoin one magnet with another; and this the rather, because a larger quantity of effluvia surrounds the iron than the magnet. Hence also it follows, that *iron is conjoined with the magnet, or the magnet with the iron, by means of spheres; that one invites and attracts the other, as it were, by a certain force; and that they are not repelled in different directions, as one magnet is by the similar or hostile pole of another; it follows also that the iron is conjoined with the magnet to the same extent to which the common sphere either penetrates or surrounds the iron; and that the whole mass of iron is conjoined with the magnet, provided the mass be penetrated or regularly surrounded; unless its weight should be greater than the force of conjunction exercised by the vorticles or sphere.*

30. *By the application and contact of the magnet and the iron, we observe that, in the compages of the iron, all the effluvia which are perfectly or partially free are disposed into a regular situation; and that the iron is thus rendered magnetical.* The vorticles of the magnet which are next to the wall are, as we have above observed, most closely colligated one to the other by the spires which are inmost; and are as it were folded into each other's embrace by planes possessing the greatest possible curvature: hence if the iron be made to approach the magnet till it comes into contact with it, then the vorticles existing in each body are joined by the most curvilinear and rapid spires; consequently the vorticles which float in the iron freely, as it were, are by a strong mechanical force reduced to the same situation; and consequently those also which flow without. Hence by means of friction, all the parts which are in a state of perfect or partial freedom, are converted into such a situation, as to be able to form, with those which are circumfluent, a regular sphere and figure. Thus it is, that from a regular

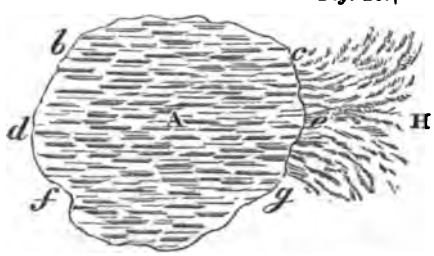
situation of the parts within the iron, magnetism exists; consequently poles and axes are formed; and around the axes a regular figure or sphere, the circles of which, by their perpetual connexion with each other, maintain a relation to the axis and the axis to the iron. Let us take the case of the effluvia in a rough piece of iron not yet rubbed by the magnet; the parts of which are in the situation represented in Fig. 19, where

Fig. 19.*



we observe an irregular connection extending round about to *b, c, d, e, f,* and where one vorticle tends to the right, another to the left, and not one is connected harmonically with another. In Fig. 20 all the parts are in a rectilinear and parallel situa-

Fig. 20.†



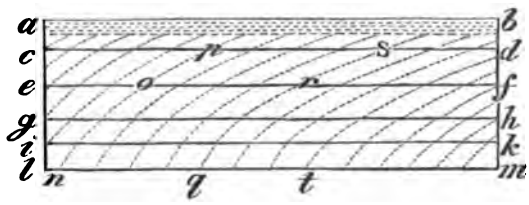
tion; hence at *c, e, g,* there is a regular conjunction, and the highest aptitude to regularity of figure. Iron that has been

* In the original, plate X., fig. 2.

† In the original, plate X., fig. 1.

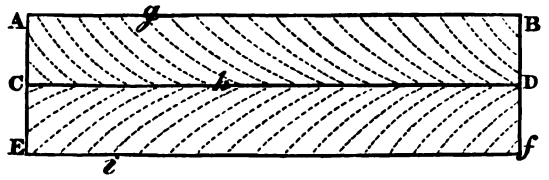
rubbed is represented by Fig. 21. For when the magnet is

Fig. 21.*



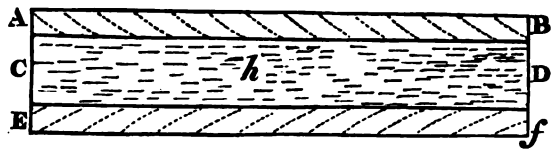
drawn from *a* to *b*, the effluvia seem to be reduced, from one extremity to another, into a parabolical or other regular figure; so that their situations are similar, as denoted by *nop* and *qr*S; hence the effluvia without may be regularly colligated with the effluvia within. Or if the friction take place in the plane of the iron lamella, and in its middle from C to D, then the effluvia

Fig. 22.†



are compelled to direct their course according to that of the friction; in order to have a constant relation as it were to the middle axis CD, and hence to conspire in the direction of the pole D. Or if the iron be too thick, as in fig. 23, and the

Fig. 23.‡



force exerted in arranging the effluvia be not great enough to be enabled to penetrate toward the middle, still the effluvia occupying the superficial part may be composed on all sides into a

* In the original, plate X., fig. 3.
† In the original, plate X., fig. 5.
‡ In the original, plate X., fig. 5.

regular situation; but inasmuch as they have no connexion with the interior effluvia, it follows that they return to their former irregular situation; the magnetism ceasing with the destruction of the regular situation. And inasmuch as the magnetic sphere extends far beyond the iron to the other part of the magnet, it follows that, by the conjunction of their spheres, not only is the iron conjoined with the magnet, but also in a long connected series the iron with the iron; the spheres of all the pieces of iron coalescing with the magnetic spheres into one. These observations are only general: in the sequel we shall proceed to particulars and to actual experiment.

CHAPTER II.

ON THE ATTRACTIVE FORCES OF TWO OR MORE MAGNETS, AND THE RATIO OF THE FORCES TO THE DISTANCES.

A PRIORI, OR FROM FIRST PRINCIPLES.

There is no one magnet absolutely similar to another, either as to its interior texture or as to the figure of its circumambient sphere. Moreover the magnetism in the same stone is subject to variations arising from the most divers causes. With regard to interior texture, there are some magnets which are exceedingly heavy, and others which are lighter. There are those which are extremely pregnant with effluvium, and others which are almost destitute of it; there are those within which are reposited, in greater or less abundance, metals, minerals, and stones of different kinds; by reason of which the connexion as well as the regular and rectilinear flux of the smallest parts is disturbed; there are others which are endowed with effluvia floating in a state of complete or partial freeness, rather than in a state of colligation, and *vice versâ;* others whose effluvia do not float from one wall to another, or from one pole to another, in a right line, but which are perforated by a regular or irregular curve from one extremity to the other, and in which the polar axes cannot be diametrically opposite to each other; there are those which possess ducts partly rectilinear, and partly curvilinear, passing through their texture; others which possess rectilinear ducts extending not to one but to several extremities of the magnet, and having a conical, triangular, or other form, whence not merely two but several poles, as it were, are origin-

ated: others there are which emit a crowd of effluvia not in a state of due colligation with the body. In the mass and figure of the magnet itself there is also a diversity. In regard to their spheres, the spheres receive their configurations according to that of the magnet. If the magnet be spherical, it is surrounded with a sphere of a different figure from the one it would have if it were elliptical, parabolical, cubical, parallelopipedal, or otherwise angular; the sphere also varies in those different figures according to the relation of the polar axis to their length or latitude, or according as it is situated obliquely at an angle;* there are spheres which approach very nearly to the circle or ellipse: there are those which approximate to other curves: there are those which, being in the closest colligation with the body from which they emanate, enclose and as it were compress each pole with the most amicable embrace. There are those which abound with heterogeneous parts, that hinder the free course of the fluxion; for there are effluvia of innumerable kinds proceeding from every body. In fine, both in regard to internal texture and external sphere, there are indefinite varieties; so that of these, as of all other entities much compounded, we may say that not one is absolutely similar to another. Hence arise such great and numerous varieties in the conjunctions and attractive forces of magnets; into which we propose to institute an experimental enquiry. To represent these diversities by lines and figures would be to open a wide field of labour. Even in one and the same stone the mechanism cannot always be alike. There are large quantities of other effluvia, some of which may disturb or break the connexions between the magnetic effluvia. The atmosphere itself is like a vehicle laden with effluvia. In the elements themselves, as in the ether, air, and fire, there are innumerable species of motions, which, in various modes and under various circumstances, may not only enter into the series and contiguous arrangement [*contiguum*] of the effluvia, but may also either relax or destroy the connexion of some of the vorticles with the axis, and consequently with the magnet. There may be minute substances

* Accedit, si axis polaris in diversis illis figuris sit secundum longitudinem, vel secundum latitudinem, vel oblique ad angulum.

also occupying the surface of the magnet, and intercepting its little foramina and outlets, and preventing the effluvia from exhaling or colligating themselves with the circumfluent effluvia. To enter into these particulars and to assign the laws according to which these effluvia act, would be a task of considerable labor; nor do I know that it would be of much use, unless we could also furnish the figures and the mechanism of the several parts.

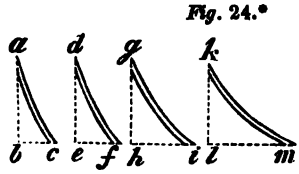
2. *The attractive force or conjunction of two or more magnets or pieces of iron, depends not only upon the axis but upon the whole circumambient sphere.* By the figure of the sphere are formed the polar axes, as we have above stated; and from the polar axis on one side, the vorticles and elementary particles deflect their course and proceed circuitously to the axis on the opposite; and from this axis to the polar side or margin of the magnet. There is consequently a connexion of the whole sphere with the axis, and of the axis with the magnetical body; and all the effluvia with their vorticles form a series and contiguous whole; whence the motion of the one is the same with the motion of the other; the motion of the parts in the equator is the same with the motion of the parts in the axis; there is thus between all a coherence which can be obtained only by regularity of figure. Magnets therefore which have their two spheres mutually conjoined, and which as it were draw and invite each other by their conjunction, not only are conjoined or drawn together by the axis, or directly, but also are sensible of the force and attraction throughout their whole sphere; nor can they be separated one from the other unless by consent of the entire sphere surrounding the magnetical body. For if the vorticles cohere in one series, and if by this coherence a regular contiguous whole be formed, then are the force and motion of one the same with the force and motion of another and of all collectively, or of the contiguous whole. Thus the attractive force depends principally upon the perfect regularity of the figure of the sphere.

3. *The attractive force is stronger at a less distance from magnets; weaker at a greater; and none in the place where the spires of the vorticles begin to embrace each other at an angle of forty-five degrees.* We have shewn above, that the force of at-

traction is stronger at a less distance from the magnet than at a greater. Thus in Fig. 18 (p. 238), A and B are two magnets; the distance between them is BA: in this case the vorticles reciprocally comprehend and colligate each other at a greater distance, thus with spires of less curvature; hence the colligation of these magnets is according to that of the vorticles or spires in *ab*. In Fig. 15 (p. 237) the colligation of the magnets is according to the colligation or conjunction in *ab*, where they combine more intimately with their spires; and still more so in Fig. 14 (p. 237), at *ab*. The colligations cannot exist anywhere else than in the line or plane of conjunction, which is the cardinal plane of each sphere. If the magnets are unequal in weight, mass, sphere, and force, then the cardinal plane cannot be in the middle distance, but will be situated as in *ab* Fig. 17 (p. 238), or *ab* Fig. 18 (p. 238), where the distance to B is greater than it is to A; because the sphere of one is larger than the sphere of the other, and consequently extends its axis to a greater distance. The circumstance of the conjunction of the spheres being similar to that of the effluvia in the plane *ab*, results from mechanical principles. For suppose a rope passing over a pulley, whose threads are strongly twisted together; and that half-way between its extremities it happens to be smaller or thinner; in this case the strength of the whole rope depends upon the strength of this particular part. Where the coherence is less, the strength of the rope is less; and upon this part it is that the entire contiguous length is dependent. Not only however does the conjunction of the spheres depend upon the intermediate ligation in *ab*, but upon the entire circumfluent sphere; because the ligation itself formed by the coalition and conjunction in *ab*, coheres with the contiguous whole.

That the mechanical colligation of the fluxions does not extend beyond an obliquity of forty-five degrees in the spiral planes, may be seen in Fig. 24, where the spire of greatest curvature is *ac*; of lesser curvature, *df*; of still less, *gi*; and approximating still nearer to a right line in *km*. If the

Fig. 24.*



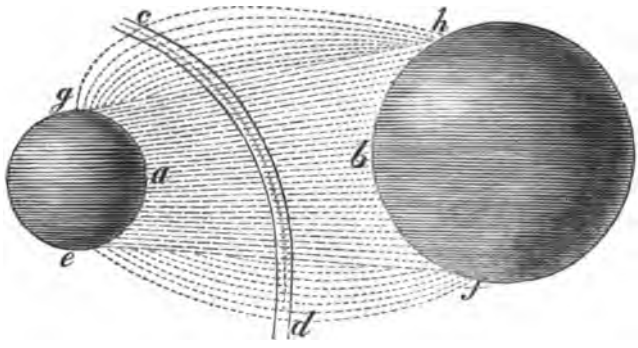
* In the original, plate V., fig 10.

side *bc* be less than the side *ba*, then there is a mutual colligation of the spiral planes; but if the side *lm* be greater than the side *lk*, then there is no such colligation; that is to say, if the angle *lkm* is more than forty-five degrees; for in this case the spire obliques itself from the cardinal plane, toward the position of a right line more from *l* to *m* than from *m* to *l* or to conjunction; as may be illustrated experimentally by screws, helices, or polished planes joined together at various angles. For the colligative forces tend to *lm* more than they do to *lk*; that is to say, more to a disjunction than to a conjunction. Hence if in Fig. 16 (p. 237) the vorticles are conjoined in their place of coalescence or cardinal plane *ab*, at an angle of forty-five degrees, they cannot beyond this present any farther force of conjunction; for from this distance the whole attractive force between the two magnets ceases. The circumstance of the magnet being able to turn the needle towards itself at a still greater distance, such as one of several ells or even ten feet, does not arise from the colligative and conjunctive force of the sphere; for the needle, when touched with the magnet, will obey any angularity of spiral. On this subject however we shall speak in the sequel.

4. *There cannot be two magnets possessing a similar attractive force. But in magnets perfectly similar, there is always a constant geometrical ratio between the attractive forces and the distances.* They cannot possess a similar attractive force, because no two magnets can be similar as to their interior texture or exterior sphere; but supposing there could be two perfectly similar, and possessing a perfectly similar force, then there would be a constant geometrical ratio between the attractive forces and the distances. For the figure of the sphere is regular: there is a regular progression of the vorticles and spiral motions along the axis: there is consequently a constant geometrical ratio of forces according to the distances—a ratio which is the simple geometrical. But inasmuch as the conjunctive force depends upon the spheres and the figure, and there is no one sphere similar to another, nor at all times similar to itself; it follows that we cannot assign any constant ratio of conjunction between any two magnets. Moreover, if any two magnets decline in the least from a perpendicular position, or

from a direct opposition to each other, there immediately arises a difference in the ratio or analogy between the conjunctive forces and the distances; as in Fig. 25. If the position of the

Fig. 25.*



magnet *a*, in regard to the position of the magnet *b*, be not direct but oblique, there will result a different intervening axis; consequently a different figure of the sphere, and thus a different conjunctive force. Hence a perfectly exact ratio between the forces and distances cannot in this case be expected. But let us proceed to experiment.

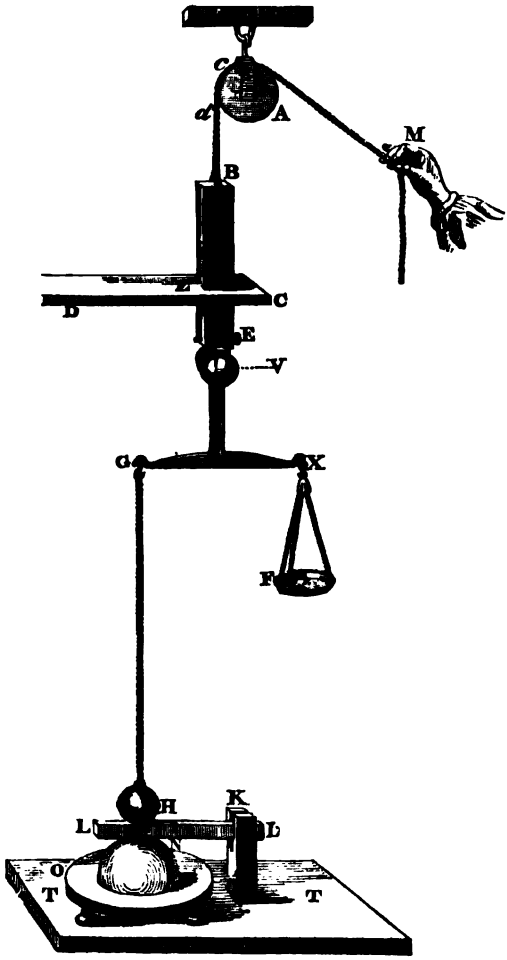
THE SAME ARGUED A POSTERIORI OR FROM EXPERIMENTS.

There are no experiments with the magnet better suited and hence more eligible to our purpose, than those which have been lately presented to the world by the very learned and sagacious PETER VAN MUSCHENBROCK; who has been so judicious in the mode of conducting his experiments. In examining, therefore, the phenomena of the magnet, and comparing them with the principles we have already laid down, I shall quote the words of this highly experienced author.

* In the original, plate V., fig. 12.

I took, says he, an extremely accurate balance, XG (Fig. 26), the pivot of which was exceedingly fine and polished, so that the beam XG could turn upon it with the utmost facility, and become depressed

Fig. 26.*



at either extremity X or G by putting in the twentieth part of a grain. In order, moreover, to make the slightest depression visible, the tongue of the beam was made to end in a very fine point, and directly opposite to a little pin V, which projected downward from the upper and central

* In the original, plate VI., fig. 2.

part, between the side bars within which the tongue moves; these bars being here expanded into the form of a ring, presented an opening through which one might see whether the tongue kept exactly opposite the pin, or inclined to one side or the other; as also the degree of declination; in other words, it might be seen whether there was any equilibrium or not. To the extremity G, I attached a cord GH, several feet long, and winding round a spherical magnet H, commonly called by philosophers a *terrella*.* This length of cord was requisite in order to prevent the magnet H from acting upon the beam GX, which was made of steel. From one end of the beam X was suspended a copper scale F, for holding weights, serving by their gravities to measure the attractive forces of the magnets.

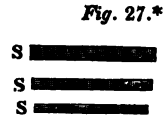
Our object being to ascertain the forces of the magnets placed at various distances from each other, it was necessary that the beam of the balance should be capable of being raised or lowered; and in order that the magnet suspended from the beam should always keep directly opposite the same point of the upper surface of the fixed magnet placed underneath, it was requisite that the beam should be so raised, that its centre should be always in the same parallel line perpendicular to the horizon. For this purpose I inserted the hook Q at the top, into a notch cut into the wooden parallelopipedon QB, in which I fastened it by the pin E. I then passed the block QB through a square hole Z cut out of the joist DC, which was fixed immovably into the wall, so that I could raise or lower the balance together with the block BQ, just as I pleased; and in order to do this with perfect facility I attached to the block the cord B*dc*M, which was conducted over a wheel A. Had the beam been suspended solely by a cord, it might have been constantly turning round in consequence of the latter twisting or untwisting according to the dryness or dampness of the weather; so that without the foregoing arrangement I could not have ventured upon making any observations. The other magnet which was to be operated on by the former H, was the *terrella* NO, placed on a round piece of board, hollowed out in the middle, in order that the magnet NO might be the more conveniently placed in any required position. This piece of board, to which three legs were attached, stood upon a strong table of wood TT, which was without iron nails or any iron at all, lest it should interfere with the reciprocal action of the magnets.

Having completed the apparatus, I proceeded to ascertain the weight of the magnet H, and of the cord GH, having first removed from its table the other magnet NO. From the hook G was then suspended a

* Because it was supposed to represent on a small scale the earth considered as a magnet.—*Translator.*

pendulum of fine wire *(filum)*, in order to ascertain the point which stood immediately under the extremity G of the beam: in this point I placed the pole of the magnet NO. I then placed both the magnets in such a position, that their axes, or lines passing through their poles, might stand perpendicularly to the horizon, and in one and the same straight line. The inferior pole of the magnet H attracted the south pole of the magnetic needle; the superior pole of the magnet N attracted the north pole of the needle; consequently the two poles of the magnets now facing each other were mutually amicable. On first commencing the experiments, I raised the magnet H to a considerable height above the inferior magnet N, and then established an equilibrium by placing a weight in the scale F. Then slackening a little the rope M*cd*B, I let down the magnet H to certain shorter distances from N; and when, by reason of the attraction between the two, the former began to fall, so as to lose the equilibrium produced by the weight in the scale F, I restored the latter by gently adding, so as to avoid concussion, other small weights which indicated the degrees of the magnetic forces at the several distances. The larger distances I measured with a compass made entirely of brass; and by these several means I could easily ascertain the attractive forces at the various distances; but when I came to take note of the forces at smaller distances, it was difficult to arrive at the different points of equilibrium; for if the weight at F was not heavy enough, then the magnet H approximated too closely to the magnet N; on the other hand, if the weight at F was a little too heavy, then the magnet H ascended too much. To obviate this inconvenience, I took some plates of brass LL, or S as marked in Fig. 27, varying from each other in thickness the twelfth of an inch; of these I provided myself with twelve. I then procured others, one of which was in thickness the $\frac{1}{24}$ of an inch, another $\frac{1}{36}$, another $\frac{1}{48}$. Then placing one of the plates upon the pole of the magnet NO, and making it fast in the notch cut into a piece of wood K, the upper magnet was lowered, until its pole came in contact with the plate and the apex of the balance-tongue stood opposite the little pin V; in which way I could ascertain the exact distance between the magnets. I then placed other small weights in the scale F, which were apothecary's measures, until the magnet H became raised by overpowering the attractive force. To prevent any mistake, I always repeated the experiment twice, placing my weights in the scale one by one with the utmost care; because had a weight been thrown into the scale from too great an altitude, or had I put in two together, the magnet H would have been raised too rapidly, and the true attraction

Fig. 27.*



* In the original, plate VI., fig. 3.

at a given distance could not have been obtained. Moreover for making my experiments, I selected the days which were fair and without wind; for as often as the air became agitated by wind, our very susceptible balance would never be at rest; so that we could not take the equilibrium, even though the apparatus was removed to a cellar; for the external air always communicated its motion to the air inside the house.

In order to omit nothing which might affect the experiment, I took note of the day of the year, the height of the barometer and thermometer, the dryness of the atmosphere, and the quarter of the wind; particulars which I afterwards found were not without their use; for I discovered in consequence that the forces of the same magnets vary at different seasons of the year, and hence that in experiments of this kind the season ought always to be taken into account.

In this description of the method of making our experiments, I have been rather diffuse; but the reader is hence enabled to satisfy himself whether they have been made with a due degree of care. At all events, if any error has crept into our experiments, as is generally the case where many are performed, it can only be a small one, and can scarely amount to much above a grain or two.

To be as concise as possible, I have arranged all the results in a table. The following are those which I obtained on July 10, A.D. 1725, when the barometer stood at $29\frac{3}{11}$ Rhenish* inches, and Fahrenheit's thermometer of mercury stood in the sun at $61\frac{1}{2}$; the weather being damp and rainy and a light west wind blowing. The two magnets employed were the two spherical ones, the diameter of ON being $6\frac{1}{2}$ inches, and of H, $1\frac{1}{3}$ inches.

EXPERIMENT I.

Distances of Magnets. Inches.	Lines.		Attractions measured by Apothecaries Grains.	Distances of Magnets. Lines.		Attractions measured by Apothecaries Grains.
5	10	=	$1\frac{1}{4}$	5	=	$43\frac{1}{2}$
4	6	=	$2\frac{1}{4}$	4	=	$50\frac{1}{2}$
3	9	=	3	3	=	62
2	4	=	9	2	=	79
1	9	=	12	$1\frac{3}{4}$	=	81
	12	=	23	1	=	140
	11	=	$23\frac{1}{2}$	$\frac{1}{2}$	=	186
	10	=	$26\frac{1}{4}$	$\frac{1}{3}$	=	240
	9	=	29	0	=	340
	8	=	$30\frac{3}{4}$			
	7	=	33			
	6	=	$38\frac{1}{3}$			

* Rhenolandicos—*Rynland or Leyden.*

From these experiments we derive the following corollaries:—

Cor. 1. Two magnets attract each other at different distances with different forces, and the nearer they are to each other the greater is the force of their attraction; which consequently is greatest when the magnets are in mutual contact. For when they were in mutual contact, their forces of attraction were equal to the weight of 340 grains, while at the distance of twelve inches their forces equalled only 23 grains.

Cor. 2. From an examination of the foregoing experiments it appears, that the attracting forces were not as yet in so great a ratio as the inverse ratio of the distances; but that the ratio was less. For when the attractive force was at the distance of half a line, it was equal to 186 grains; at double the distance or one line, it was equal to 140 grains; whereas had it been in the inverse ratio of the distances; we should have had the weights which follow:—

Distances of Magnets. Lines.		Calculated Weights.	True Weights.
$\frac{1}{2}$	=	186	186
1	=	93	140
2	=	$46\frac{1}{2}$	79
4	=	$23\frac{1}{4}$	$50\frac{1}{2}$
8	=	$11\frac{1}{8}$	33

If again we fix upon other distances, we equally find the real attractions to be greater than the forementioned calculation indicates.

Distances of Magnets. Lines.		Calculated Weights.	True Weights.
$\frac{1}{3}$	=	240	240
1	=	80	140
3	=	$26\frac{1}{3}$	62
9	=	$8\frac{7}{9}$	29
27	=	3 almost	9

Cor. 3. If we now attend to the proportion of the attracting forces, we by no means find it to be constant; for at $\frac{1}{2}$ line distance the weight was 186 grains; and this number is to 140 grains as $1\frac{23}{70}$ to 1; a proportion which would always obtain in the other following numbers, supposing the ratio to be constant. But $140 : 79 :: 1\frac{61}{79} : 1$. Also $79 : 50\frac{1}{2} :: 1\frac{57}{101} : 1$. And $50\frac{1}{2} : 33 :: 1\frac{17}{66} : 1$.

In all these cases, however, the real proportion is different from the foregoing. Now since innumerable proportions may be elicited, I have taken no little pains, in order from the given numbers to extract some one regular proportion either simple or compound; but hitherto they have been fruitless.

EXPERIMENT II.

Being however unwilling to rely upon experiments made only with the foregoing magnets, I entertained a hope that I might perchance make some further discovery by the employment of other magnets: for it seemed to be possible, that some heterogeneous matter either in one or the other might operate as a cause of a less accurate and constant proportion between the attracting forces and the distances. I consequently left the same large spherical magnet NO in its place on the table; but from the beam GX was suspended another magnet, naked or unarmed, (such as is used in making experiments.) The form of this magnet was a parallelopidon, 2 inches high, $2\frac{1}{2}$ long, $1\frac{7}{12}$ wide. This magnet I so suspended, that both poles were in a line perpendicular to the horizon; as also in the same line with the two poles of the other magnet. The experiments thus conducted furnished the subjoined results.

They were made July 11, 1725, when the barometer was at $29\frac{5}{24}$ inches, and Fahrenheit's thermometer at 62°; a wind blowing from the north and the weather being dry and fair.

Distances of Magnets. Inches	Lines.		Attractions measured by Apothecaries Grains.
12	0	=	0
9	0	=	$1\frac{1}{8}$
8	0	=	$1\frac{1}{2}$
7	6	=	2
7	0	=	$2\frac{1}{2}$
	12	=	$70\frac{1}{2}$
	11	=	$75\frac{1}{2}$
	10	=	85
	9	=	92
	8	=	100

Distances of Magnets. Inches.	Lines.		Attractions measured by Apothecaries Grains.
	7	=	106
	6	=	111
	5	=	132
	4	=	149
	3	=	173
	2	=	205
	1	=	240
	$\frac{1}{2}$	=	270
	0	=	300

EXPERIMENT III.

It appeared to be desirable to ascertain, whether the attractive forces of the same magnet were equally strong at all times; whether the vicissitudes of heat and cold produced any variation; whether the forces of the magnet in winter were different from what they were observed to be in summer. With this view I repeated my librations of the magnetic forces on the 24th day of December in the same year; using the same magnets and the same apparatus as before. The results were as follow:—

Distances of Magnets. Inches.	Lines.	Attractions measured by Apothecaries Grains.	Distances of Magnets. Inches.	Lines.	Attractions measured by Apothecaries Grains.
15	6	= 0		9	= 94
13	6	= 0		8	= 106
12	0	scarcely = $\frac{1}{20}$		7	= 114
11	0	„ = $\frac{1}{8}$		6	= 131
10	0	„ = $\frac{1}{4}$		5	= 146
9	0	= $\frac{1}{2}$		4	= 172
7	6	= $1\frac{1}{2}$		3	= 190
7	0	= $2\frac{1}{2}$		2	= 215
	12	= $70\frac{1}{2}$		1	= 250
	11	= $78\frac{1}{2}$		$\frac{1}{2}$	= 290
	10	= 87		0	= 340

Thus we found, that when the magnets were in immediate contact, the attracting forces were the same; as was also the case when the spherical magnet H was in immediate contact with the spherical magnet NO. But when the magnets were at the same distances from each other as were indicated in the former table, a great difference was observable between the attractions; we remarked also, that the attractions were not in the inverse ratio of the distances, but in a less ratio; likewise, that the attractions did not increase or diminish in any constant proportion as the distances increased or diminished.

Thus in our second experiment, the proportion of the forces at the same distances we found to be as follows:—

Distances.		Forces.		Proportion.		
$\frac{1}{2}$	=	270				
			::	$1\frac{1}{8}$	:	1
1	=	240				
			::	$1\frac{7}{21}$	:	1
2	=	205				
			::	$1\frac{66}{149}$	:	1
4	=	149				
			::	$1\frac{49}{100}$	:	1
8	=	100.				

But in our third experiment the proportion of the forces at the same distances was as follows:—

Distances.		Forces.		Proportion.		
$\frac{1}{2}$	=	290				
			::	$1\frac{4}{25}$	:	1
1	=	250				
			::	$1\frac{7}{43}$	:	1
2	=	215				
			::	$1\frac{43}{173}$	:	1
4	=	172				
			::	$1\frac{33}{53}$	:	1
8	=	106				

Hence it is evident that there is not the same proportion of the

attractive forces in winter as there is in summer, if we compare the proportions exhibited by the two experiments.

EXPERIMENT IV.

In addition to the foregoing experiments, I took two other magnets, both of which were in the form of a parallelopipedon. Of these I suspended one from the beam GX, the other I placed upon the table TT, taking as much care as I could that both the polar axes should be in one and the same line perpendicular to the horizon. The size of one magnet was as follows; in length $2\frac{3}{4}$ inches, breadth $2\frac{1}{2}$ inches, thickness $1\frac{1}{2}$ inches; the size of the other magnet was, in thickness 2 inches, length $2\frac{1}{2}$ inches, breadth $1\frac{7}{12}$. The results of the experiments made with these two magnets are as follow:—

Distances in Inches and Lines.		Attractions measured by Apothecaries Grains.		Distances in Inches and Lines.		Attractions measured by Apothecaries Grains.
9 ,, 4	=	0		3 ,, 11	=	$4\frac{1}{2}$
8 ,, 6	=	1		3 ,, 1	=	$7\frac{1}{2}$
7 ,, 9	=	1		2 ,, 5	=	$12\frac{1}{2}$
7 ,, 3	=	1		1 ,, 8	=	$21\frac{1}{2}$
6 ,, 5	=	1		10	=	45
5 ,, 11	=	$2\frac{1}{2}$		5	=	95
4 ,, 11	=	$2\frac{1}{2}$		0	=	128

These experiments lead to no other conclusion concerning the proportion of the magnetic forces than is derived from the previous ones.

EXPERIMENT V.

I next took the large round magnet NO, the diameter of which was $6\frac{1}{2}$ inches, and which I had used in experiments 1, 2, 3. This I placed upon the table TT, upon which it stood immovably, and from the beam I suspended the parallelopidal magnet, which I had used in experiment 4, and which was in length $2\frac{3}{4}$ inches, breadth $2\frac{1}{2}$, and thickness $1\frac{1}{2}$. In this case the forces of attraction were observed to be as follow:—

Distances in Inches & Lines.		Attractions measured by Apothecaries Grains.	
19 ,, 0	=	0	
18 ,, 0	=	1	
17 ,, 4	=	$1\frac{1}{2}$	The weight was the same at various other distances.
13 ,, 0	=	2	The weight was the same at various other distances.

Distances in Inches & Lines.		Attractions measured by Apothecaries Grains.	Distances in Inches & Lines.		Attractions measured by Apothecaries Grains.
9 „ 9	=	$2\frac{1}{2}$	4	=	209
10	=	122	3	=	218
8	=	136	2	=	241
7	=	164	1	=	273
6	=	170	0	=	340
5	=	187			

From the foregoing results it is again evident, that there is no constant proportion between the forces and the distances; for the actions of these magnets were not in the simple inverse ratio of the distances, inasmuch as at the distance of 1 line, the action equalled 273 grains, and at 2 lines the attraction equalled 241 grains.

If the actions were in the inverse ratio of the distances, then at the distance of 2 lines the weight required to counterpoise the attraction would be $136\frac{1}{2}$ grains or the half of 273.

Now the forces themselves are in the proportion of 1 to $1\frac{32}{273}$, and if they continued in the same proportion, decreasing as the distances increased, then at the distance of 4 lines, they would equal $215\frac{218}{301}$ grains. But the experiment shews that they equalled 309 grains, consequently the computation does not correspond to the observations. It would in like manner be easy to shew, that the results of other experiments were equally far from exhibiting any constant proportion between the forces and the distances, use what mode of computation we might.

Indeed the same circumstance has been remarked by the celebrated Taylor, who from his experiments concludes that the magnetic forces did not correspond to the distances, but that the proportions experienced a decrease which was greater at the larger distances than at the smaller. The same conclusion is derivable also from my own experiments. This philosopher however has added, that in the experiments which he made with two needles at a distance of $2\frac{1}{2}$ inches, the forces did not vary in a ratio as great as the squares of the distances, and that at a distance of 10 inches the forces varied more than as the cubes of the distances, when the exponent was $3\frac{1}{4}$. *See Philosophical Transactions*, No. 368, p. 204.

From these five experiments we learn nevertheless, 1. That the actions of two magnets upon each other do not exist at every point of distance, but that the distance of their action is determinate; for in experiment 4 it did not extend as far as 10 inches, nor in experiment 5 as far as 19 inches: at least our highly susceptible balance did not indicate any symptom of their action. Consequently were I to reason

solely from these experiments, I could not infer that the actions of magnets extended to very considerable distances. From other experiments however which were made with needles extremely mobile, it was evident that the magnets acted upon them at much greater distances than could be observed by the adoption of the former method, inasmuch as the needle turned upon its pivot with far less friction than the beam upon its axle. Still from the action of the magnet upon the needles we might notwithstanding draw the same inference as in the former case, inasmuch as even the needles at a distance of several feet were not set in motion by the magnet, for I never found the action of the magnet extend beyond 14 Rhenish feet, when to a needle six inches long I presented a most excellent magnet.

2. If we compare these five experiments with each other, we may observe that the forces of the several magnets did not extend to the same distance; but of some to a larger, of others to a smaller distance. Thus in experiment 5 it extended to 18 inches, in experiment 4 to 9 inches, in experiment 3 to 13 inches, in experiment 2 to 12 inches. Nay, I had a large magnet, the action of which was sensible at a distance of 11 feet, and sometimes at a distance of 14 feet.

3. Moreover, although in experiments 1, 2, 5, we observed that the attractive forces of the magnets were at equal linear distances very different; that in the fifth experiment they were greater than in the third; and in the third greater than in the first; still it is surprising that when the magnets were in immediate contact their forces were the same, being equal to 340 grains; and this is the more surprising, when we consider that the magnets suspended from the beam, and which we had employed in three of the forementioned experiments were unequal in volume, and different in weight and form; when we consider also that the forces of these magnets were exceedingly different one from the other; for the best magnet, although small, was the round one employed in the first experiment, while the forces of the magnet employed in the fifth experiment were only moderate, but those of the magnet employed in the third experiment were exceedingly feeble. Besides in the first experiment one globe was in contact with another globe, in the third and fifth one globe was in contact with a plane superficies. It is true that in all three cases the contact was at one point, but beyond this point of contact the two spherical surfaces receded more from each other, than the spherical from the plane surface. On a consideration of these circumstances, I began to doubt whether the action of magnets depended upon any magnetic effluvia, or any external fluid, call it by what name we may;—a subject to which I afterwards gave further attention. For if the action of two

magnets depended upon their mutual effluvia, then would their action be greater in proportion to the greater quantity of effluvia, and this quantity would flow in a much greater degree from the more than from the less replete magnets, consequently a much greater quantity of effluvia would have proceeded from the magnets which I used in the first and fifth experiments, because these excelled the one employed in the third experiment. In immediate contact, however, the forces of all the magnets were observed to be equal.

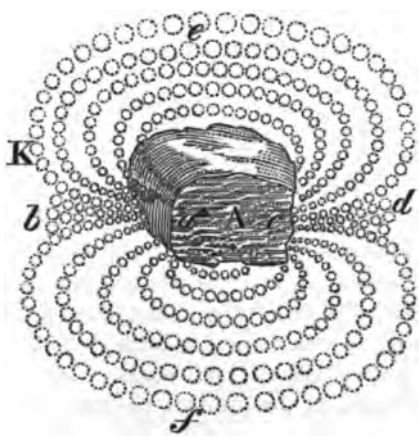
CHAPTER III.

ON THE ATTRACTIVE FORCES OF TWO MAGNETS WHEN THEIR POLES ARE ALTERNATED.

A PRIORI OR FROM FIRST PRINCIPLES.

The magnetic sphere about one pole is not similar to the one about the other pole, nor is the axis at the south pole extended similarly to that at the north pole; but in the figure of the sphere there is always on each side a difference; consequently at each pole, there is not exerted the same force; nor is the attractive force of two magnets the same if the poles are alternated, that is to say, if the ends of the magnets be inverted and homogeneous poles be opposed to each other. Thus let A be the magnet,

Fig. 28.*



* In the original, plate V., fig. 11.

c its north pole, *cd* the northern axis of its sphere, *a* the south pole, *ab* the southern axis. We affirm that on the side *cd*, the figure of the sphere or the extension of the axis is not always either the same or similar with that on the other side *ab*; and consequently that the force at one pole is either greater or less than the force at the other, and *vice versâ*. For supposing that the stone is magnetic only on one side; that on this side only its pores are rectilinear; that on one side it is more pregnant with effluvia than on the other; in this case, its figure on one side is different from what it is on the other; hence the sphere which arises and is formed out of the nature and figure of the magnet, originates on one side an axis larger and stronger than the axis on the other.* Consequently there is no one magnet possessing on one side a force and figure of sphere similar to that on the other; hence neither is the attractive force of two magnets similar if their poles are alternated or inverted.

THE SAME A POSTERIORI OR DERIVED FROM EXPERIMENTS.

Muschenbroek, who was so highly skilled in conducting magnetic experiments, thus continues. Hitherto, says he, I had been examining the attractions of the two poles in both magnets; but I thought it desirable to ascertain whether the obverse poles exercised the same, or different attractive forces from those which were exerted in the former case.

EXPERIMENT VI.

Consequently the small spherical magnet H, which I had employed in the first experiment, I again suspended from the beam by a cord, but so that the other pole now hung downwards. I next placed upon the table TT as before the larger spherical magnet NO, whose other pole in the present case was turned upwards, both poles being placed in the same line perpendicular to the horizon; and having taken all the precautions mentioned in the previous chapter, I observed the mutual

* See Chapter II., Art. 1.

attractions of the magnets, at the different distances mentioned before; the date of the observations being July 12, A.D. 1725.

Distances in Inches and Lines.	Attractions measured by Apothecaries Grains.
4 „ 6	= 1¾
4 „ 2	= 2¼
3 „ 9	= 2¼
2 „ 4	= 9
1 „ 9	= 12
12	= 26
11	= 28
10	= 31
9	= 34
8	= 36
7	= 39

Distances in Inches and Lines.	Attractions measured by Apothecaries Grains.
6	= 44
5	= 48
4	= 59
3	= 68
2	= 89
1	= 132
½	= 155
⅓	= 225
0	= 310

Now if we compare these forces with the others above noticed, we shall perceive between them a considerable difference, and observe that in all these instances the forces are less than in the former. Consequently the two poles of a magnet do not exert upon another magnet the same forces of attraction, but different.

EXPERIMENTS VII. AND VIII.

As I possibly might have been too precipitate in my conclusions had I trusted to only a single experiment, I extended my observations to many. Consequently the large round magnet ON which I had used in experiments 1, 2, 5, I placed immovably on the table, and a different magnet from the one I had hitherto used I suspended from the beam, on Feb. 17, A.D. 1726: the poles which mutually attracted each other I placed obversely one to the other, so that I might be able to note the equality or inequality of the attractions. The following are the results in each case, and which I have put together in the following order that the eye may the more easily comprehend at a single glance the diversity of the forces at the same distance.

EXPERIMENT VII.

Distances in Lines between the first two Amicable Poles.	Attractions measured by Apothecaries Grains.
12	= 57
11	= 63
10	= 66
9	= 70
8	= 79

EXPERIMENT VIII.

Distances in Lines between the first two Amicable Poles.	Attractions measured by Apothecaries Grains.
12	= 72
11	= 78
10	= 87
9	= 94
8	= 106

EXPERIMENT VII.

Distances in Lines between the first two Amicable Poles.		Attractions measured by Apothecaries Grains.
7	=	83
6	=	90
5	=	101
4	=	113
3	=	124
2	=	148
1	=	168
0	=	228

EXPERIMENT VIII.

Distances in Lines between the first two Amicable Poles.		Attractions measured by Apothecaries Grains.
7	=	114
6	=	131
5	=	146
4	=	172
3	=	190
2	=	215
1	=	205
0	=	340

CHAPTER IV.

ON THE ATTRACTIVE FORCES OF TWO MAGNETS WHEN THEIR AXES ARE PARALLEL, OR WHEN THE EQUINOCTIAL OF THE ONE LIES UPON THE EQUINOCTIAL OF THE OTHER.

A PRIORI OR FROM FIRST PRINCIPLES.

When two or more magnets are so situated in regard to each other that the equinoctial of one lies upon the equinoctial of the other, in this case the spheres of the two magnets combine into one that is larger and form a certain large axis between the poles of the magnets. By the mutual application to each other of two or more magnets, the spheres are mechanically compelled to combine their motions into a state of harmony or equilibrium. For similar parts could not subsist together and be put in motion in one and the same volume, unless the motion of one part was accommodated to the motion of the other; for of two spires in mutual proximity one cannot flow in a direction contrary to the other, one helix cannot turn in a direction opposite to that of the other. Nature complies not with motions dissimilar, contrary, and heterogeneous; because she is mechanical. In one and the same volume her concords are no where discordant; nor can any one equilibrium be opposed to itself; for even could this be the case, it must by the very motion and mechanism of nature be immediately rendered concordant and unanimous. In the present case, inasmuch as the motions are purely and highly mechanical, and together with the motion, the forces also and powers, in each vorticle, and likewise each distance or spire from the centre; it follows that when the two spheres are

further light upon the laws of magnetism; but that in the physical sciences we are sometimes led to discoveries more by accident than by foresight, so that in order to omit nothing relative to this method of examination, I made preparation to pursue my experiments. The large round magnet which I had employed in the two preceding experiments, I placed, as before, immoveably upon the table, in such a position, that the line joining the poles was perpendicular to the horizon, as in the preceding cases; but the magnet having the form of a parallelopipedon, and which I had used in some of the foregoing experiments, I suspended from the beam in such a manner, that the line joining the poles was parallel to the horizon. Now this parallelopipedon having six polar sides, two of which had already been examined, there remained four others as a subject of investigation. I therefore first examined two of the sides which were opposite and parallel to each other, then in like manner the other two. The results of the examination are exhibited in the two following tables.

The two opposite sides of the parallelopipedon, when made successively to face the same pole of the round magnet, exhibited forces of attraction at the several distances as follows:—

EXPERIMENT IX.			EXPERIMENT X.		
Lines.		Attractions measured by Apothecaries Grains.	Lines.		Attractions measured by Apothecaries Grains.
12	=	32	12	=	32
11	=	34	11	=	34
10	=	32	10	=	37
9	=	34	9	=	40
8	=	38	8	=	46
7	=	43	7	=	52
6	=	48	6	=	56
5	=	56	5	=	69
4	=	63	4	=	76
3	=	74	3	=	94
2	=	94	2	=	115
1	=	114	1	=	146
0	=	178	0	=	196

The two other sides of the parallelopipedon placed opposite the pole of the round magnet exhibited the forces at the several distances as follows:—

EXPERIMENT XI.			EXPERIMENT XII.		
Lines.		Attractions measured by Apothecaries Grains.	Lines.		Attractions measured by Apothecaries Grains.
12	=	20	12	=	13
11	=	20	11	=	13
10	=	24	10	=	16
9	=	25	9	=	16
8	=	29	8	=	21
7	=	34	7	=	24
6	=	36	6	=	28
5	=	44	5	=	34
4	=	51	4	=	39
3	=	59	3	=	51
2	=	73	2	=	63
1	=	93	1	=	83
0	=	135	0	=	128

How considerable is the variation between the attractions of these four sides! Yet if the substance of the magnet were homogeneous, and if the axis of the poles lay midway between the two sides of the parallelopipedon, ought not the attractions of the four sides to have been equal? I see no reason why they should not; and yet the magnet I employed seemed to possess the make I have mentioned; but whether according to the exactest nicety I confess I had no means of ascertaining. It is certain however that the observations presented in the foregoing tables, and exhibiting the degrees of the several forces, very much differ from each other.

CHAPTER V.

ON THE DISJUNCTIVE AND REPULSIVE FORCES OF TWO OR MORE MAGNETS WHEN THE COGNOMINAL OR INIMICAL POLES ARE APPLIED TO EACH OTHER.

A PRIORI OR FROM FIRST PRINCIPLES.

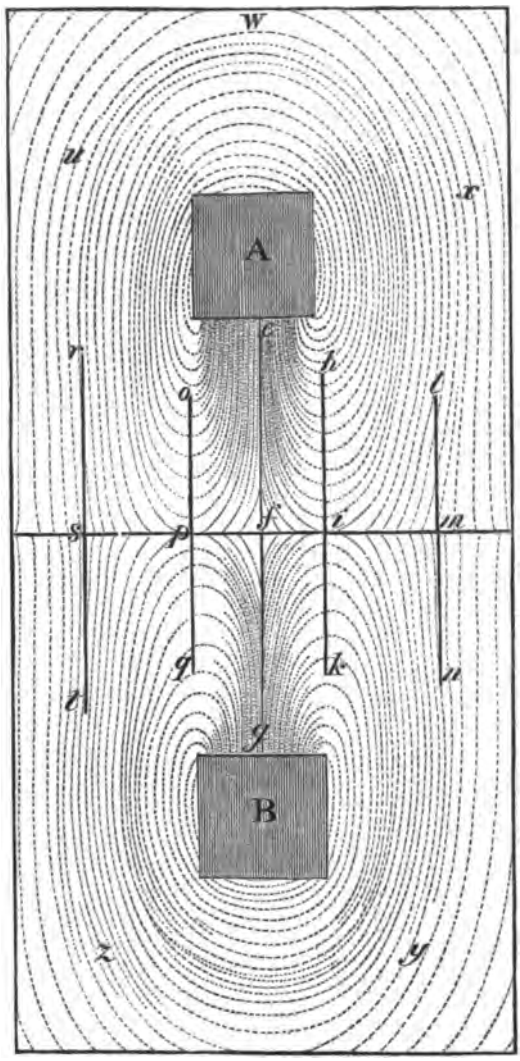
If two or more magnets be so applied to each other, that the south pole of one be opposed to the south pole of another, or the north pole of one to the north pole of another, that is, if two cognominal poles are opposed to each other at different distances, then the spheres of each magnet will coalesce into one large sphere. The individual parts or vorticles of each sphere are similar one to the other; and if the spheres be applied to each other, they must, like two volumes, coalesce and combine into one. The individual parts are the vorticles, which form the sphere solely by their own spiral motion; therefore if the two spheres touch each other, and either of themselves, that is, spontaneously,—or else unwillingly, that is, by force, apply themselves one to the other, then there arises only one sphere;* for the vorticles tend to a state of harmony and equilibrium, of which if they are incapable, the motions are destroyed, and together with the motion the sphere, and together with the sphere the figure, and consequently together with these the magnetism.

Still however in the middle distance between the magnets thus applied, the situation and fluxion of the vorticles are nearly contrary the one to the other; but at each side they more inflect themselves toward their natural and homogeneous position. Consequently in the middle of the column thus formed, there is a disjunction of the parts; but at the sides or laterally, a conjunction.

* Fit ex una sphæra, aut ex uno volumine unum.

Thus in Fig. 30. Suppose A and B to be two magnets, *g* and *e*

Fig. 30.*

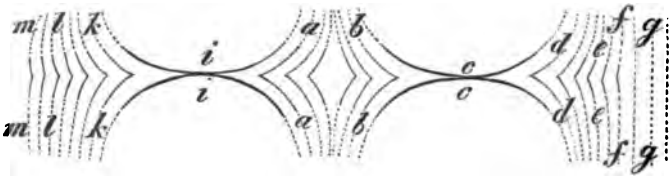


their cognominal poles, whether south or north. Then inasmuch as in this position the fluxions or gyrations of the parts are contrary the one to the other, the vorticles which are in the diameter and middle distance, cannot possibly mutually dispose

* In the original, plate VII., fig. 1.

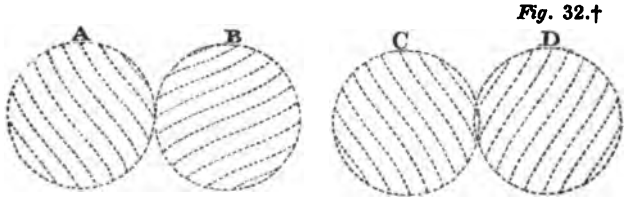
themselves into a similar situation or be reduced into an harmonic or concordant motion, as is the case in *f*. But inasmuch as in nature which is mechanical, all discordant motions tend to one which is unanimous, and similar, and equilibrant, the vorticles on both sides are more and more compelled to deflect themselves from their middle point of coalition to *p* and *i*, where they are parallel and neither conjunctive nor disjunctive. Still further on toward the sides, they so apply themselves to each other as to originate a motion homogeneous and similar as far as *m* or *s*, where there again exists a ligation of all the vorticles; so that at a certain distance from the middle there is formed a ligation of each sphere, or, by reason of this ligation, a conjunction of each magnet. Nearer however to the middle, or at *f*, there is a disjunction; because there is a mutual opposition and contrariety of the motions of the vorticles which mutually touch each other. The spiral gyrations of the vorticles at the cardinal plane or middle coalition of each sphere, are, by sequence from our principles, similar to each other. Thus in Fig. 31; the spires *aa* and *bb* flow in a direction contrary to each

Fig. 31.*



other; but in a direction less contrary toward *ii*; and still less contrary at *ii*, where the position of all is parallel and horizontal and where there is neither disjunction nor conjunction. From this place they grow oblique and perpendicular toward their homogeneous position; as from *c* toward *d, e, f, g*; or from *i* toward *k, l, m*. For if, as in Fig. 32, the motions of the fluent spires were

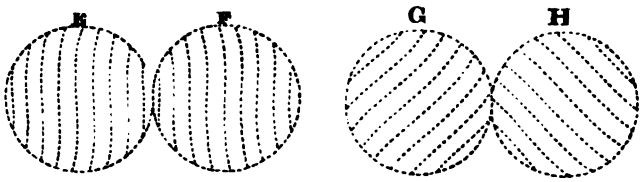
Fig. 32.†



* In the original, plate VII., fig. 4.

† In the original, plate VII., fig 3.

Fig. 32.*



such as GH or AB, then would the motion of one repel from itself the motion of the other; but this it would do in a less degree in CD, in a still less in EF, where neither any ligation nor solution of the spires can take place. The circumstance of the vorticles being disposed in such a manner by the opposition of cognominal and similar poles, results from the mechanism of their motions: for from principles of mechanism it is, that in the middle distance and diameter they cannot be immediately inflected, that from the middle they begin to deflect themselves gradually, that at some distance from the middle they dispose themselves evidently into a state of harmony and equilibrium as regards their situation and motion, that in the middle there is thus a state of repugnance and repulsion, but at the sides a state of ligation and conjunction. Indeed the mechanism of the motions may be presented to ocular examination, if we take a number of wheels loosely connected in a line like the links of a chain, and set them revolving among each other upon their axes: in which case we shall see those which are directly opposed to each other exciting a state of commotion, we shall see one running counter to another, one driving another and itself being driven into a contrary direction, some repelling and others being themselves repelled; in fine, we shall see a state of mechanical conflict. Those however which did not revolve in such opposite directions, if free space were afforded, would not present such a scene of collision, but would gradually and orderly accommodate themselves in a body to the motion of others opposing them, till finally all collision would cease, and all would become harmonized into one motion and disposition. In like manner the magnetic vorticles, if they run counter to each other by reason of a contrariety of motion and position, commence among themselves a

* In the original, plate VII., fig. 3.

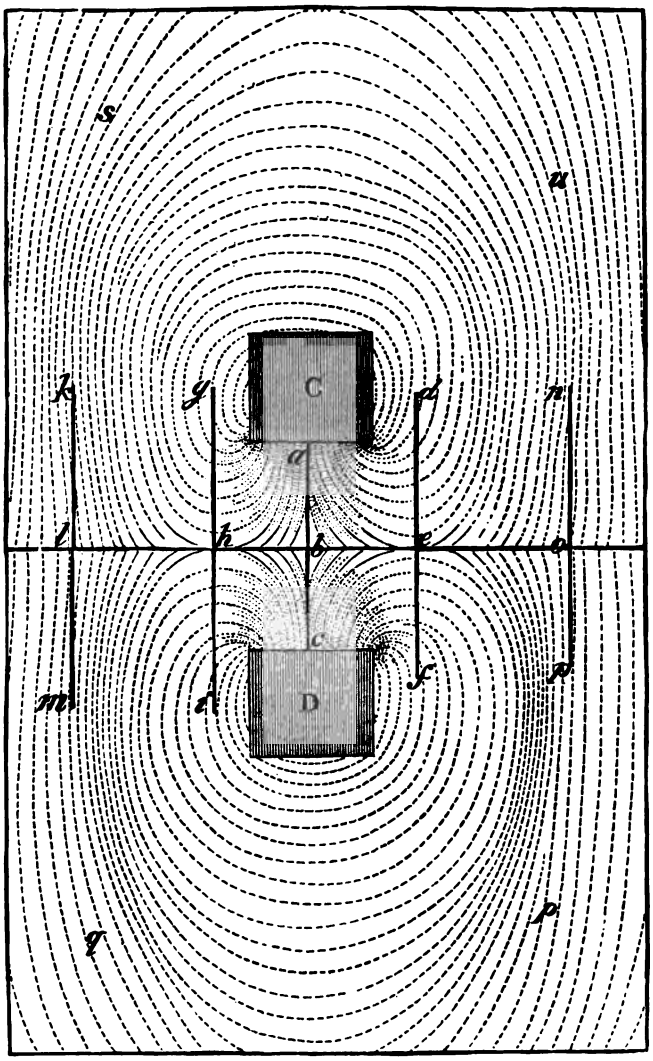
state of conflict, and as in a battle, begin the onset impetuously, and if they have not free space, with unallayed energy contend one with the other, and in their congress enfold and endeavor to commingle each other's spires and motions. Where however, by reason of the obstacles arising from other vorticles, they are not able to unfold themselves and their interior forces, they do not present such a scene of discordance and collision, but amicably consociate their motions and spires, and embrace each other as if in confederation. Thus does nature with her motive forces tend to a state of equilibrium.

2. *If however the cognominal poles be turned toward each other, then the magnets are partly repelled and partly attracted; and their repulsive force is increased according to the distances and ratio of the spheres, but at a smaller distance becomes proportionally diminished.* Thus in Fig. 30 (p. 271), where the magnets are represented as at the greater distance from each other, their repulsive force is within the boundaries *opq* and *hik*, because all the vorticles within that latitude or column are compelled to observe a greater and less oblique position. At lesser distances between the magnets, the conjunctive force becomes greater and greater within *hik* and *lmn*, or between *opq* and *rst*. Thus in the middle the sphere has a repulsive force, at the sides a conjunctive force; and inasmuch as the repulsive overcomes the conjunctive, it follows that the disjunction becomes greater and greater according to the distance and according as the vorticles meet the nearer each other and with more interior spires. If now the magnets be brought still nearer to each other, as in Fig 33, the conjunctive force becomes increased, because the space or column *eo* or *hl* is enlarged. And were the force of ligation at *eo* and *hl* as great as the repugnance at *eh*, there would result an equality and similarity between the two, nor would there exist at that distance any repulsion or conjunction. Therefore two or more magnets, having inimical poles opposite to each other, partake of both forces, and present, with the same equality and inequality, increments and decrements at various distances according to the connexion and extension of their spheres,—all of which may be made a matter of calculation, provided the magnets be absolutely similar to each other.

Hence also it follows, that *when two or more magnets are*

opposed to each other, then in the space outside their perpendicular line, they confederate their energies [conniti], *let the poles observe*

Fig. 33.*



however small an obliquity, or let the magnets be removed however slightly out of the diametric line of opposition: for the repulsive

In the original, plate VII., fig. 2.

force still remains either greater or less according to the distance within its own space, such as *abc,def*, Fig. 33; but in case the magnets were removed even in the least out of the diametrical line, in other words, in case their poles were placed obliquely to each other, then also the repulsive space would assume an obliquity; in like manner *lh* would become greater or less than *eo*, and consequently the conjunctive force would become greater or less on one side than on the other, the repulsive space giving to the sphere an oblique direction: and so on.

3. *Between the distances and repulsive forces of two magnets, there cannot be any constant rule of proportion, unless the magnets together with their spheres are absolutely similar:* just as in like manner there cannot be any constant rule of proportion between the distances and conjunctive forces of two or more magnets; for if in respect to their virtue, the rectilinear direction of the parts, the quantity of effluvia, the force of ligation at their termini, their own figure and that of their sphere, as also an exactly and diametrical and opposite position, the magnets were absolutely similar, in this case the ratios between them would be constant, and we should no longer have to ascertain them from experiment.

4. *If therefore two or more magnets be so applied to each other, that the homogeneous or amicable poles mutually face each other; then from two or more spheres arises a single larger sphere having two poles, one at each end of the magnet, and the distance between the magnets becomes its axis, equalling the entire side of each magnet. If however two or more magnets are so applied to each other, that their poles are parallel, but their equators opposed to each other, then from two or more spheres arises a single larger one, having four poles, two supplied by each magnet; the case however is otherwise if cognominal or inimical poles are opposed to each other. From these circumstances, assumed as a basis, we may proceed to ascertain the nature of the coalition of the spheres, or what must be the figure of the larger sphere if more than two magnets be brought together, as also what it must be if two or more be placed opposite to each other in another position more or less oblique from the axes or equator and at various distances and angles.* In eliciting these truths, bringing them under general rules, and reducing them to geometrical princi-

ples, philosophy might employ her proportions and analytical computations for many an age, while geometry alone would fill numerous volumes with its illustrations by curves, spaces, and lines.

A POSTERIORI OR FROM EXPERIMENTS.

EXPERIMENT XIII.

Magnets not only mutually attract, but also mutually repel each other; and both the poles of one magnet repel both the poles of the other; the poles however which repel are different from the poles which attract each other. Being desirous of ascertaining with regard to the repulsions of the magnets, whether they were greater or less than the attractions, whether they observed any regular or irregular proportion to the distances, I thought that I might very effectually accomplish my wishes by pursuing the same method which I had adopted in ascertaining the attractions; with this difference, that whereas in the latter case I had placed the weights in the scale to equipoise the attractions, I should have now to place them upon the magnet, in order to make it heavier, and tend to approach the lower magnet, the more it was repelled, or sent in an upward direction.

The large round magnet NO was again placed immoveably on the table, while the other magnet, which was the parallelopipedon used in experiment 5, I suspended from the arm of the balance; and then equipoising it by placing weights in the opposite scale, I made the following observations on the several degrees of repulsion:—

Distances in Inches and Lines.		Repulsions measured by Apoth.'s Grains.		
14	„ 0	=	$\frac{1}{2}$	
13	„ 0	=	$\frac{2}{4}$	
11	„ 9	=	1	
10	„ 9	=	$\frac{1}{2}$	
10	„ 4	=	0	Or simple equilibrium, such as existed before the experiments
9	„ 10	=	0	
9	„ 4	=	$\frac{1}{4}$	
9	„ 0	=	$\frac{1}{4}$	
8	„ 3	=	$\frac{3}{4}$	

Distances in Inches and Lines.		Repulsions measured by Apoth.'s Grains.	
7	„ 9	=	1
7	„ 6	=	$1\frac{1}{2}$
6	„ 9	=	2
6	„ 4	=	$2\frac{1}{2}$
5	„ 9	=	2
5	„ 4	=	2
5	„ 2	=	$2\frac{1}{2}$
4	„ 9	=	3
3	„ 10	=	1

In bringing the upper magnet nearer to the lower, I found it was no longer repelled but attracted; for at the distance of 3 inches and 6 lines

the attraction was equal to 7 grains. I am not aware that a greater anomaly could possibly be remarked than was shewn by these repulsions, which at the great distance of 14 inches were considerable, and at the lesser distance of 10 inches ceased altogether, then again at a lesser distance down to 4 inches continued to increase, at a still lesser distance decreased, and finally became changed into an attractive force. Polinierius, moreover, in his physical treatises, page 279, has observed that the pole of the magnet, which at a larger distance repelled the extremity of the mariner's needle, at a smaller distance attracted it. In either of these cases, the effects are very anomalous; and hence I thought it was better to repeat my experiment with another magnet, and the same which I had used in experiment 3, either to afford me the opportunity of making some further discovery with respect to the mutual repulsions of magnets, or else to confirm the former anomaly. The results were as follow:—

EXPERIMENT XIV.

Distances in Inches and Lines.		Repulsions measured by Apoth.'s Grains.	Distances in Inches and Lines.		Repulsions measured by Apoth.'s Grains.
13 ,, 0	=	0	1 ,, 11	=	12
11 ,, 11	=	$\frac{1}{2}$	1 ,, 4	=	17
10 ,, 9	=	$\frac{3}{4}$	12	=	24
9 ,, 9	=	1	10	=	24
6 ,, 1	=	2	7	=	25
5 ,, 1	=	$3\frac{1}{2}$	6	=	$25\frac{1}{2}$
4 ,, 0	=	$6\frac{1}{2}$	5	=	$27\frac{1}{2}$
2 ,, 9	=	$11\frac{1}{2}$	4	=	29
2 ,, 3	=	13	0	=	44

These experiments relating to the repulsions of the magnets required much greater dexterity than was requisite in ascertaining the attractions, for I remarked that the magnet which was suspended perpetually deviated from the right line passing through the poles; hence I was obliged to attach it to a copper wire, and this wire to the beam, in order to retain it perpetually in one and the same right line over the other magnet.

A greater order or regularity is however observable in these experiments than in those made with the former magnet, since the repulsion increased as the distance decreased, and continued to do so down to the point of contact.

To any one however who examines the foregoing table of repulsions, it will be evident that there is no determinable proportion between the

forces and distances, in like manner as none could be found between the attractions.

The attraction however is much greater than the repulsion; for when the magnets were in immediate contact and the attraction was equal to 340 grains, the repulsion was equal only to 44 grains; and by comparing our third experiment with the present, the great degree of difference between the two is easily observable.

EXPERIMENT XV.

I felt desirous moreover to ascertain whether the repelling forces of each pole of the same magnet were equal, or in what manner they varied; consequently the magnet employed in the last experiment and which hung from the beam, I inverted so that the other pole now faced downwards: I also in like manner inverted the round magnet placed upon the table, and then proceeded to take the following observations:—

Distances in Lines.		Repulsions measured by Apoth.'s Grains.	Distances in Lines.		Repulsions measured by Apoth.'s Grains.
12	=	30	5	=	34
11	=	32	4	=	32
10	=	32	3	=	28
9	=	33	2	=	27
8	=	34	1	=	25
7	=	36	0	=	13
6	=	36			

The results here are so remarkable, that I at first doubted whether the experiments had been rightly conducted; but on repeating them with greater care, I found the repulsions precisely the same. At the distance of 12 lines these repulsions were considerable; they continued to increase to the distance of 7 lines, after which they decreased until at the point of contact the repulsion became equal only to 13 grains. It may be asked, therefore, what there is in magnets which produces this anomaly? Shall we say that the stone we examined consisted of parts exceedingly heterogeneous, some of which attracted and others repelled; and that these opposite forces, proceeding from the same point in the magnet, disturbed the proportion either of simple repulsion or attraction? This would appear to be the probable view of the case; so that he who wishes to know the degree of the repulsion only, ought to have in view also the attractive force of the same poles, and to add this to the repelling force, the sum of both which would then indicate the degree of the repelling force. It is evident however that the attraction to-

gether with the repulsion is given in experiment 13, in which at the distance of 3 inches and 6 lines and less, the attraction prevailed over the repulsions, and hence the magnet suspended from the beam was attracted, not repelled; in experiment 15, at the distance of 5 lines the proportion of repulsion was less than that of attraction, hence likewise the repulsion seemed to diminish as the distance diminished, while nevertheless the repulsion had undoubtedly increased in proportion as the magnets were made to approximate to each other; this repulsion however was so disturbed by the attraction, that the greatest irregularity was the consequence,—an irregularity which was observable in the experiments themselves, since at the distances of 10, 11, 4 lines the repulsions were equal, and at the distance of 7 lines the repulsion was greatest. In this view of the subject I was confirmed by adding to the repulsions the attractions observed between these magnets in experiment 3, for then a certain regularity became observable, the repulsion being greatest at the point of contact, less at any given distance between the magnets, and decreasing as the distance increased. This will be evident from the following table, which exhibits the attractions observed in the third experiment and the repulsions observed in the fourteenth experiment, together with the sum of the attraction added to the repulsion.

Distances in Inches and Lines.	Attractions measured by Apoth.'s Grains.	Distances in Inches & Lines.	Repulsions measured by Apoth.'s Grains.	Sum Total of Repulsion.
12 „ 0	= $\frac{1}{20}$	11 „ 11	= $\frac{1}{2}$	$\frac{3}{40}$
11 „ 0	= $\frac{1}{8}$	10 „ 9	= $\frac{3}{4}$	$\frac{7}{8}$
12	= $70\frac{1}{2}$	12	= 24	$94\frac{1}{2}$
10	= 87	10	= 24	111
7	= 114	7	= 25	139
6	= 131	6	= $25\frac{1}{2}$	$156\frac{1}{2}$
4	= 172	4	= 29	201
0	= 340	0	= 44	384

Now attending to the numbers which express the sum of the repulsion, I am not able to observe between these and the distances any constant proportion. If there be any it will not be great, and will be less than the simple inverse proportion of the distances, commencing the computation from the point of contact; for $6 : 4 :: 201 : 134$, instead of $156\frac{1}{2}$. Again, $7 : 6 :: 156\frac{1}{2} : 134\frac{1}{7}$, instead of 139. Again, $10 : 7 :: 139 : 97\frac{3}{10}$, instead of 111. Again, $12 : 10 :: 111 : 92\frac{1}{2}$, instead of $94\frac{1}{2}$. Still I doubt not that some constant proportion would be found to exist between the distances and the repulsions, provided the latter alone could be obtained, and calculated separately from the

interference of any other agency; nay, even the attractions themselves may possibly observe a constant ratio, but are probably disturbed by the repulsions; for each pole of the magnet exhibits both a repulsive force and an attractive, consequently from one and the same pole there issue an attractive and also a repulsive force. When the amicable poles of two magnets are turned toward each other, the attraction prevails over the repulsion; when the inimical poles face each other, the repulsion prevails over the attraction; wherefore the action is always compounded of attraction and repulsion. Hence the two proportions which compose the action observed in the experiments must be mutually extricated from the observed quantities, in order to be made the subject of a distinct and separate computation—a process which will be found extremely difficult; until however we have succeeded in it, we shall be unable to arrive at the true proportion of attraction and repulsion. In such a state of things it will be better to suspend our judgment, and simply to record our observations; thus leaving it to posterity, from an increase of data and a more matured knowledge, to elicit further results. Nor will my silence upon this matter be much to my disparagement; for the wisest Florentine philosophers who have treated of the magnet, have furnished us only with the results of experiments, without the addition of any speculations; a course they have pursued lest they should offer only fictions for truths, hypotheses for demonstration, and ashes for treasures.

Having from the foregoing experiments been unable to ascertain any proportion between the forces, I was led to doubt whether it was possible, by any of the methods I had hitherto adopted, to detect, at the various distances, the proportion between the forces, even supposing such a proportion to exist; since the two magnets acted one upon the other, and hence the forces proceeding from the two by their mutual encounter disturbed the proportions. On the other hand, if I employed only a single active magnet, the other being deprived of its active forces, there appeared to be some hope of detecting much more easily the proportion of the forces. An inert magnet of this kind could however be supplied only by pure and good iron, such as it is when just taken out of the fire, possessing no magnetic force, neither struck nor violently seized with the tongs, but having been gently and cautiously handled. I now therefore turned my attention to experiments made with the magnet and iron, such as I am about to describe in the ensuing chapter.

Both in conducting and describing these experiments I have been prolix, perhaps even to a degree of irksomeness, but not without reason; because had I made a mistake in one experiment, I had thus the better chance of discovering it in another. Besides, the most distinguished of

all natural philosophers, Sir Isaac Newton, has assumed a different proportion of the magnetic forces; so that I ought not to treat so important a subject lightly, or content myself with only a few experiments. For the celebrated author I now mention has observed in his *Principia*, book i., sec. xv., prop. 85: "If one body is attracted by another, and the attraction be very much stronger when the former is contiguous to the attracting body than when it is separated even by the smallest interval of space; the forces of the particles of the attracting body, as the body attracted recedes, decrease in a greater than the duplicate ratio of the distances from the particles." Again, in book iii., prop. vi., cor. v., we find the following remark: "The force of gravity is of a different kind from the magnetic force, for the magnetic attraction is not in proportion to the matter attracted. Some bodies are more attracted, others less, many not at all. Moreover, the magnetic force in one and the same body may be made greater or less; sometimes it is far greater in proportion to the quantity of matter than the force of gravity, and in receding from the magnet does not decrease in the duplicate but almost in the triplicate ratio of the distances, as far as I have been able to ascertain from some rough experiments I have instituted." Would that the experiments here referred to, and from which he had made his foregoing inferences, had been recorded! Perhaps a man of such amazing penetration in the mathematical sciences has found out some method of separating the attractions from the repulsions, and discovered that they decrease in the triplicate ratio of the distances. As however he has come to no further conclusions on this subject, we can neither reject nor receive his opinion; and if we consulted only our own experiments, we should say that the attractive forces of the magnet do not decrease in so great a ratio of the distances.

CHAPTER VI.

ON THE ATTRACTIVE FORCES OF THE MAGNET AND OF IRON.

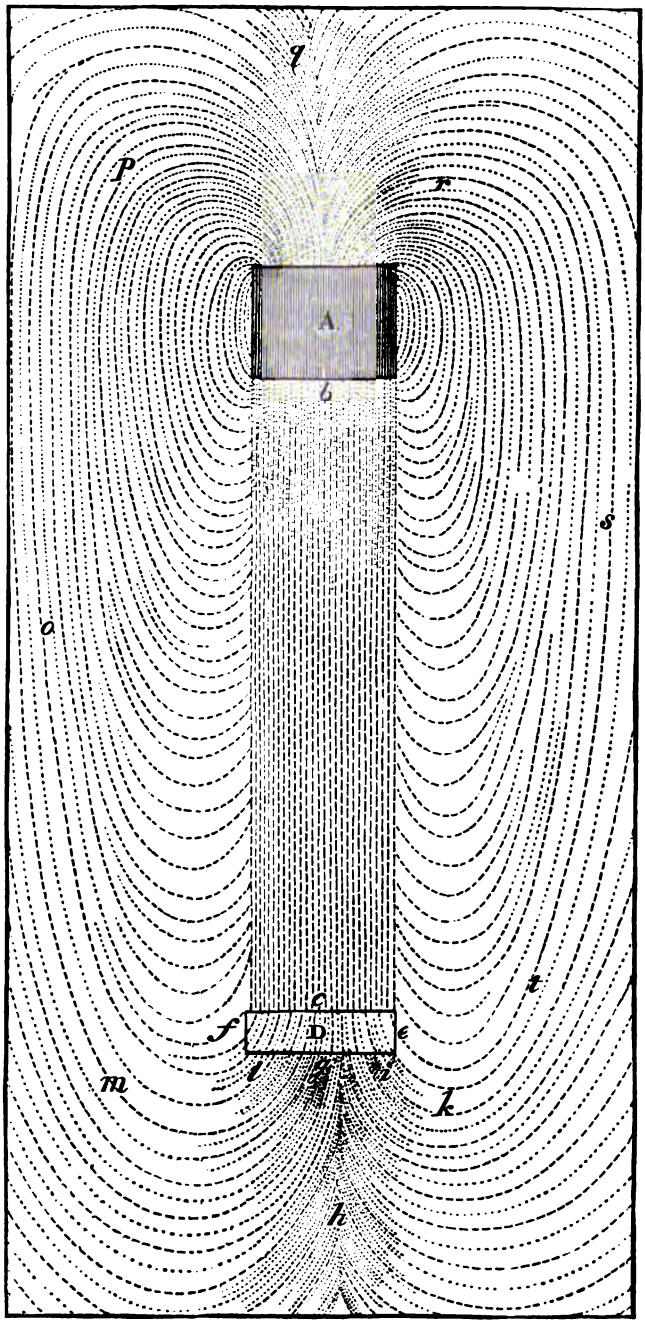
A PRIORI OR FROM FIRST PRINCIPLES.

When iron is applied to the magnet or the magnet to iron, then from out of two spheres there exists one that is larger, and which encloses both the magnet and the iron, but not in like manner as when one magnet is applied to the other. We have already treated of the way in which two spheres combine into a larger one, when one magnet is applied to the other. But as the phenomena produced by the magnet in its action upon iron are so very palpable, and so much excite the wonder of the spectator, it may be worth while to present to view the causes of these phenomena, as explained by the principles already laid down. We learn from the First Chapter of this our Second Part, that the sphere surrounding the magnet is of a figure perfectly regular; that the effluvia exhaling from iron are purely magnetical, but not cohering one with another so as to form a sphere perfectly regular and as it were returning into itself; consequently that there is a crowd of effluvia besetting the iron but possessing no orderly sequence, no regular figure, no geometrical arrangement, (except in so far as it extends on all sides from the iron as radii,) consequently having no mechanism enabling it to operate upon the neighbouring sphere by means of reciprocal ligation. For unless a sphere be of such a nature as to have its parts connected together into a regular configuration, series, and sequence, and to return again into itself so as to connect one portion of itself with another, it is possessed of

no contiguity, it has no relation to an axis, nor has the axis any relation to the iron as a magnet, consequently there is no magnetic force. On the other hand, if two spheres are rendered contiguous by approximation, and if one of them be regular and possess a colligation of its parts, while of the other the parts are loose or unattached to each other, the first will dispose the second into a regular situation of parts, and reduce it to a geometrical figure like its own. For the individual parts or vorticles of the sphere surrounding the magnet, are upon mechanical principles reduced into a regular sphere; and if there be a further addition of vorticles, these also become reduced into the same and similar sphere. For the effluvia surrounding the magnet, are by the orderly fluxion of the vorticles themselves urged into a state of order; an operation which is purely mechanical; because it is in a regular figure that the greater force and connective power reside. Hence the greater the quantity of effluvia, the larger the sphere around the magnet, and *vice versâ*. Now by the approximation of the iron there is a fresh accession of effluvia truly magnetic; which are consequently brought into a series and consociation, with those which surround the magnet in regular order. Hence on the part of the iron the sphere is enlarged; and, according to the mechanism, no other common sphere can be formed than one similar to the sphere, Fig. 34, where A is the magnet, D the iron, *b* the pole of the magnet. In this case all the intermediate vorticles of effluvia dispose themselves into the situation of an axis, and with one consent proceed from the magnet toward the iron and beyond it; so that all the volume of effluvia, together with its vorticles at *h*, become reduced into one common sphere: whence on the side of the magnet facing the iron the axis is elongated beyond the iron, and then turns and curves itself back, almost in the same manner as if there were no iron; besides which, on the part of the iron, the axis is carried out to a greater distance. What is the nature of the common sphere of two magnets, and what the difference between this and the former, will be seen in the figures.

If therefore the two spheres, the one of the magnet, the other of the iron, coalesce into one; if consequently both the bodies are in one and the same kind of contiguity, in one and

Fig. 34.*



* In the original, plate VIII., fig. 3.

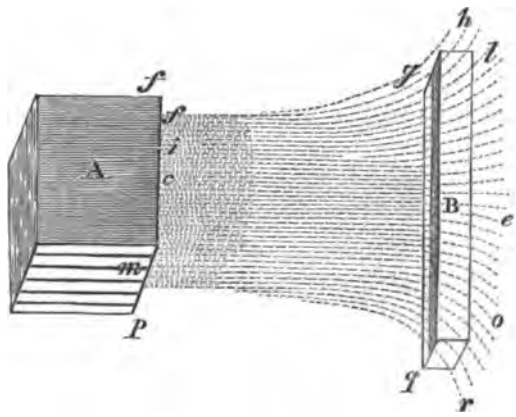
the same stream and volume; if they are thus connected together by a rectilinear position of the fluent vorticles; it follows that *the action of the magnet upon the iron is the same with the action of the iron upon the magnet.* The case may be illustrated by supposing weights appended, one to each extremity of a piece of wire, so that the two weights being thus connected together, the one cannot be moved without the other. If we draw the one on the right, then the one on the left hand follows; if we draw the one on the left, the one on the right hand follows. By means of one and the same wire, the one weight follows the motion of the other, and the action of one is thus the action of the other.

2. *The reciprocally attractive force of the magnet and the iron is greater than the attractive force of two magnets;* as is evident from the coalition of the two spheres into a single large one. The whole distance between the iron and the magnet coalesces into one common axis, which, having its beginning in the magnet, extends itself out beyond the iron; and by circumflexion from the side, unites itself with the common sphere; whence each body becomes fastened to the other by one and the same axis. The common sphere, however, which embraces and encloses two magnets, does not possess an intermediate axis similar to the one we have just described; for in this case each magnet has its own axis, which it sends out to meet the other; whence in the intermediate distance or plane of coalition, the force is according to the distance from each magnet. In the mutual application of the iron and the magnet, the axis, as is evident from our plate, proceeds from the magnet toward the iron; whence the iron is in the same connexion with the magnet, not only as to its surface opposite the magnet, but likewise as to its interior parts, and its other surface also. Thus in Fig. 34 (p. 285), there is not only a nexus at *c* but also in the very compages of the iron, or with the interior texture D of its parts, as also on the other side *il.* Thus does the whole mass of the iron lie in the same stream, vein, and direct contiguity with those of the vorticles of the magnet; and forms a connexion with the magnet on both sides, as also within its own interior parts. Moreover there is added a considerable portion of effluvia truly magnetic; and

consequently the magnet acts upon the iron more strongly than upon another magnet; upon which indeed it cannot act, except by a coalition of the vorticles in the intermediate distance.

3. *The magnet exercises the greatest force upon iron of a given proportion of mass and thickness; a less degree if the iron be too thin, or if it be too thick.* This follows from the causes before mentioned. For the iron coheres with the magnet, because all its parts are in the same stream, connexion, and contiguity; both those which are in the surface, and those which are interior. If the iron be too thin, there are fewer parts which cohere in the stream; if it be too thick, the iron is not traversed regularly by the stream, nor does the axis, which in the other case extended beyond the iron on the opposite side, now do so, but has its termination and evanesces in the compages of the iron; so that it can no longer, as in the former case, operate on both sides and in all directions, as may be seen in Fig. 35, where

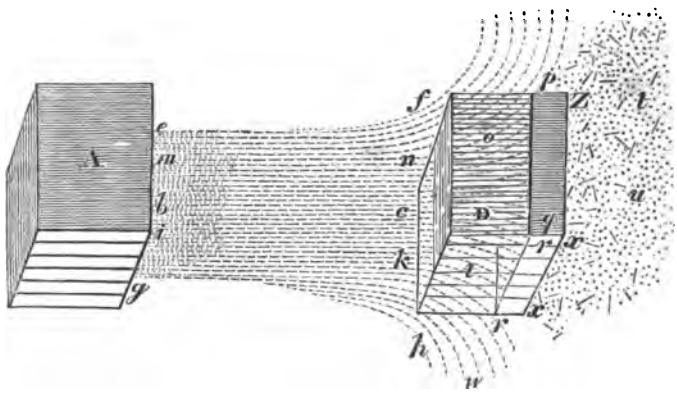
Fig. 35.*



the iron B is penetrated by the common axis extending toward *e* and *o*, and is thus entirely surrounded by one and the same direct current. But in Fig. 36 the iron is not penetrated regularly except as far as *pqr*; hence on its other side no axis is formed; and consequently at *Ztux* no regular figure. Whence there exist no magnetic virtue and power, because nothing of mechanism. The nature of the sphere of the effluvia sur-

* In the original, plate VIII., fig. 1.

Fig. 36.*



rounding the iron, may be seen in Chap. XII. of the present Part.

Iron, like all other kinds of metals, abounds in interior spaces and interstices, in which flow effluvia with vorticles similar to those which are fluent without. Hence those which flow freely in the larger interstices may be reduced into the same order and connexion with those which are circumambient; thus is an axis formed on each side, and running throughout the iron if its thickness be not too great. Hence it follows, that *in regard to the mass and thickness of the iron there is a maximum and minimum, upon which the magnet exercises its greatest force.*

4. *The magnet exercises its greatest degree of force upon iron of a given proportion in size and surface; a less degree if the iron be too small; and a less also if it be too large.* If it be too small and does not equal the entire breadth of the axis or of the stream, it follows that the plane or area exposed to the magnet is too little to allow the whole force of the magnet to develope itself; for in this case, it operates on both sides upon a smaller surface, while nevertheless it is capable of operating upon a larger. The breadth of the axis between the magnet and the iron is proportioned to the polar plane or surface of the magnet, and to the plane or surface of the iron. If the plane of the iron be very small, then the intermediate axis at the iron is very small; and consequently there is the less attractive force.

* In the original, plate VIII., fig. 2.

But if the iron opposed to the magnet be very large and spacious, then there is opposed to the magnet an area that is larger, and which is occupied by a larger or wider current. But inasmuch as the axis penetrates to the other side of the iron, and thence curves itself back into the figure of a sphere, it follows that both above and below, or at the sides, the action of this sphere upon the iron is contrary to and reacts upon itself; thus the real amount of the attractive force of the iron and the magnet is the difference between the action and reaction, as in Fig. 37, where A is the magnet, B is the iron; the dimension opposed to the magnet is *feBhi*; the common axis passes beyond, whence it begins to curve itself back, and to retrograde, as from *k* toward *w*, from *l* toward *fe*, from *o* toward *p*, or from *n* toward *i*, and thus it acts with a contrary force upon *h* and *i*, or upon *f* and *e*. Consequently by means of this contrariety of force the direct action becomes less, whence also the conjunctive force is similar in amount to the difference between the two actions. Hence it follows that *in regard to the size and surface of iron, there is a maximum and minimum, upon which the magnet exercises its greatest force. In like manner iron of a determinate size ought at least to equal the polar plane of the magnet, cxz.*

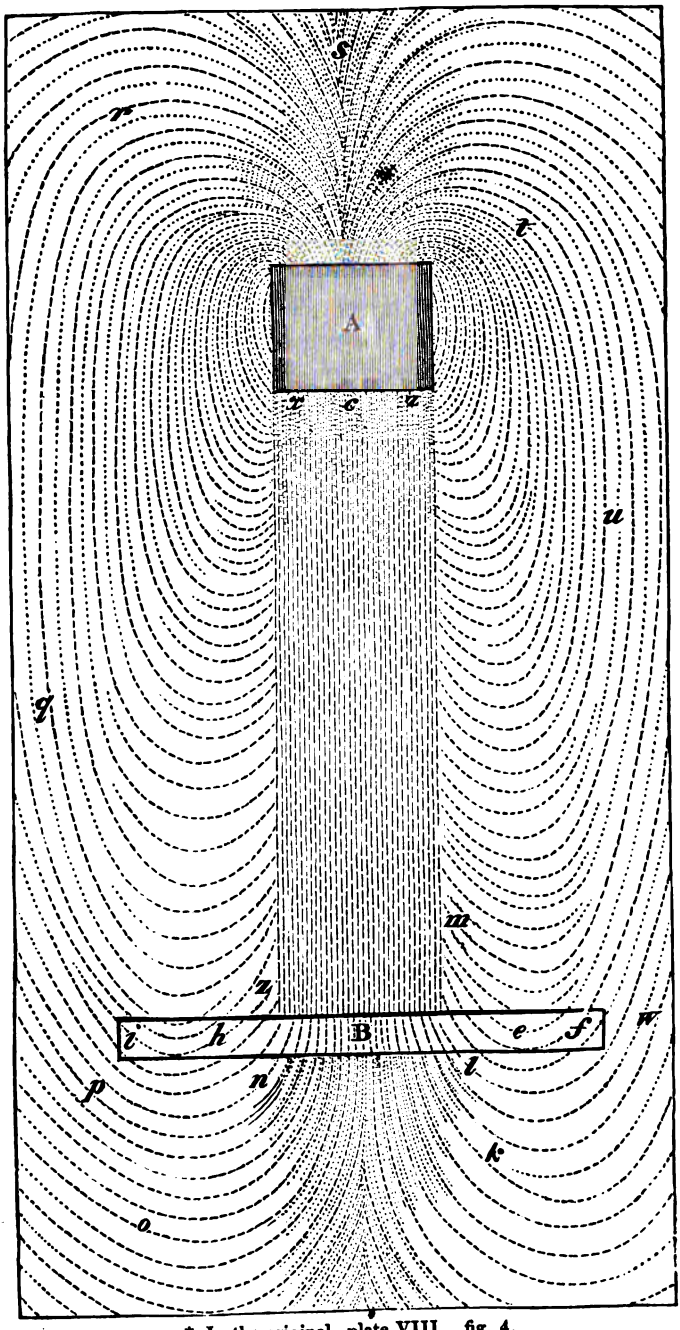
A POSTERIORI OR FROM EXPERIMENT.

If, as before, a magnet be suspended by a long cord from the beam of a balance, and weights be placed in the opposite scale to equipoise the magnet; if a mass of iron be fixed immoveably below and a few inches from the magnet and in a line with it passing through the iron and the magnet perpendicularly to the horizon, the magnet will then descend toward the iron; in which case

> Flagrat anhela silex & amicam saucia sentit
> Materiam, placidosque chalybs cognoscit amores.

Now if we wish to make the magnet keep at the same distance from the iron, it will be requisite to throw several weights into the scale, which by their gravity will thus raise the magnet, and as it were pull it

Fig. 37.*



* In the original, plate VIII., fig. 4.

away from the iron with as much force as the magnet exercises in approaching it. The additional weight beyond that which was originally thrown into the scale to produce the equilibrium, shews the degree of the attraction of the magnet to the iron; and consequently by this expedient we learn the mode of determining the magnetic forces exercised upon iron at various distances from each other.

In whatever way the magnet be turned, while continuing to be attached to the beam, it always approaches the iron.

This experiment proves that one magnet acts not only upon another magnet, but also upon iron. Nor ought this to excite our surprise. For the magnet is only a stone consisting of good iron together with an intermixture of earthy parts. The stone derives its virtue not merely from its composition of earth, but from its possession both of earth and iron; for this reason its forces are the stronger in proportion to its greater degree of iron and of weight. That the particles of iron confer a force upon the stone may easily be proved; for when a piece of iron had been fixed into a stone and remained in that position for several years, and the parts corroded with rust had permeated the pores of the stone, the stone became magnetic; as indeed, according to what I have before observed, has been evidenced by repeated trial, and confirmed by De La Hire, in his observations inserted in *l'Hist. de l'Acad. Roy., Ao.* 1705, where he says, he enclosed a piece of wire in a stone, but so placed, that its length lay in the direction observed by the magnetic needle. After ten years the stone was found to be a true magnet, the wire having been corroded by rust. On another occasion he rubbed some wires upon a magnet, before enclosing them in a stone, being desirous of ascertaining whether a stronger magnet might not thus be produced; but in this case he did not observe that the stone became possessed of any greater magnetic powers. The iron therefore which is in the magnet exercises its power of attraction in connexion with the earth which is mixed up with it; if therefore this should act upon the iron parts which constitute another magnet, it is not to be wondered at if it should act also upon pure iron, or on the purest kind of magnet possessing no admixture of stone; for this we may call pure iron. Altogether in the same manner it is that the magnet acts upon all bodies possessing any intermixture of iron; nay, possibly even upon those bodies which are possessed of no iron, but have only the same earthy attractive matter. For it is in this way that it acts upon certain plants; upon burnt bricks of an exceedingly red color, as Cabæus has remarked, book i., chap. xvii., page 63; upon the *caput mortuum (colcothar)* of vitriol; upon the shining and black dust supplied by Indian sand, and which never contracts a red color *(rubi-*

ginem), of which we shall speak further in the sequel: upon the black dust which remains after the distillation of linseed oil and oil of turpentine, as is remarked in the *History of the Royal Academy, August* 1704: upon the pomegranate *(panatum)*; upon any precious stone *(gemma)*, provided it be of a deep color, according to Boyle; (see the *Acta Lips., August*, 1693, p. 182); upon the stone of Lough Neagh calcinated, as is observed by Molyneux in the *Philosophical Transactions*, No. 166; also upon the impurities of glass, according to Helmont, page 727. Whence we are led to see the error of Pliny, who, in his *Natural History*, book xxxiv., chap. xiv., in his observations upon iron, says, *it is the only kind of matter which receives the forces of the loadstone.*

Inasmuch however as all Action is equal to Reaction, it is not possible for the magnet to act upon iron, unless the iron act reciprocally upon the magnet, and therefore approaches the magnet in the same manner as the magnet approaches the iron. Being however desirous to confirm this position by experiment, I suspended a magnet from the end of a long string attached to the beam of a balance, and produced an equilibrium by putting a weight into the scale on the opposite side. Then a mass of iron of the same gravity with the magnet, I suspended from another beam by four cords or strings, distant one from the other, so that the magnet and the iron were almost in the same perpendicular line; and in this case also I produced an equilibrium. As soon as the two were brought so near to each other as palpably to operate one upon the other, the iron approached toward the magnet and the magnet reciprocally as much toward the iron. Hence in order that the two bodies might remain separate from each other, it was requisite to place a greater weight in the scale at the end opposite to the beam from which the magnet was suspended; by which means the magnet was raised: it was next requisite to place upon the iron with great nicety an equal quantity of weight by which it should be proportionably depressed, and as it were pulled away from the magnet. This being done, an equilibrium resulted; whence it is evident, that the action of the magnet upon the iron is equal to the reaction of the iron upon the magnet. The same fact may be exemplified in another manner. Thus if we place the iron and the magnet, each in its own little boat, and let them float upon plenty of water, each will approach the other with an equal impetus, and mutually meet at the middle point between them. Let us however proceed to our other experiments, in which we endeavoured to reduce the operations of the iron upon the magnet to a matter of calculation.

EXPERIMENT XVI.

I took a mass of iron which was in the form of a parallelopipedon, the base of which was 224 lines of an inch square; its length $5\frac{1}{2}$ Rhenish inches. This mass, which had never touched a magnet, I placed upon a table, so as to stand immoveably: I then suspended a magnet (which was also of the form of a parallelopipedon, and which I had used in my fourth experiment) from a rope annexed to the beam of a balance; so that the axis connecting each pole was perpendicular to the horizon, and passed through the axis of the iron. The magnet which was brought into a state of equilibrium before making the present experiment, I let down at various distances successively from the iron, as in experiment 2. I then took account of the weight which it was requisite to place in the opposite scale in order to restore the equilibrium, and which was always equal to the attractive forces of the magnet and iron. The results may be seen in the following table.

Distances of Magnets in Inches and Lines.	Attractions measured by Apothecaries Grains.	Distances of Magnets in Inches and Lines.	Attractions measured by Apothecaries Grains.
3 „ 7	= 1	7	= 29
2 „ 11	= $1\frac{1}{2}$	6	= 32
2 „ 6	= 2	5	= 44
1 „ 7	= 6	4	= 52
1 „ $4\frac{1}{2}$	= 10	3	= 72
11	= 14	2	= 96
10	= 16	1	= 110
9	= 17	0	= 180
8	= 21		

EXPERIMENT XVII.

But since the foregoing parallelopipedon of iron was extremely large and heavy, I caused another to be made of the same weight with the other magnet examined in experiment 4; and which exposed to the suspended magnet a surface equally large with that of the preceding; for I was of opinion that the attractive forces would thus be found to be the same as in experiment 4, when the iron was similar to the magnet, except that it was not so thick, in consequence of the greater weight. The experiment, made with the same magnet as in the preceding case, furnished the following results:—

Distances of Magnets in Inches and Lines.	Attractions measured by Apothecaries Grains.	Distances of Magnets in Inches and Lines.	Attractions measured by Apothecaries Grains.
5 ,, 0	= 1	6	= 76
3 ,, 3	= 2	5	= 96
2 ,, 0	= 8	4	= 109
12	= 35	3	= 131
11	= 37	2	= 179
10	= 43	1	= 231
9	= 47	½	= 343
8	= 57	0	= 720
7	= 66		

EXPERIMENT XVIII.

Hitherto it is the magnet that has been suspended. I was now desirous therefore, in turn, of suspending the iron, and letting the magnet rest upon the table. Consequently I now suspended the iron parallelopipedon, the base of which was 224 lines square, and 5½ Rhenish inches long. This parallelopipedon was attached by a long cord hung longitudinally from the arm of the balance, and was then brought into a state of exact equilibrium. I next placed upon the table the spherical magnet NO, with its pole turned upwards in such a manner that the line connecting the poles passed through the axis of the iron. This arrangement produced, at different distances from the magnet, the following results:—

Distances of Magnets in Inches and Lines.	Attractions measured by Apothecaries Grains.	Distances of Magnets in Inches and Lines.	Attractions measured by Apothecaries Grains.
4 ,, 3	= 0	9	= 106
3 ,, 10	= 1	8	= 121
3 ,, 1	= 4	7	= 140
2 ,, 11	= 7	6	= 164
2 ,, 5	= 10	5	= 201
1 ,, 7	= 24	4	= 229
1 ,, 4	= 37	3	= 285
12	= 61	2	= 361
11	= 70	1	= 472
10	= 84	0	= 1312

EXPERIMENT XIX.

Before examining the preceding observations, I will first take notice

of certain additional experiments which I think are not unworthy of attention. These I made with the view of ascertaining the difference between the attractions of the same magnet, when the mass of iron was smaller, or of a different figure, or when it was placed in a different situation. I therefore took the foot of the armature of a magnet, which had first been made red hot in order to divest it of its magnetic power, and which is represented in Fig. 38. This foot ABCD was only a thin lamina of iron, weighing two ounces; to which was appended the little cubic foot EF, the square side of which F, and which was the one now opposed to the magnet, was about nine lines square. In this case, the attractions between the body and the magnet, at the several distances, were as follow:—

Fig. 38.*

Distances of Magnets in Inches and Lines.	Attractions measured by Apothecaries Grains.	Distances of Magnets in Inches and Lines.	Attractions measured by Apothecaries Grains.
4 ,, 6	= 0	9	= 37
3 ,, 10	= 1	8	= 40
3 ,, 7	= 1¼	7	= 43
2 ,, 5	= 3½	6	= 49
2 ,, 0	= 6½	5	= 54
1 ,, 11	= 7	4	= 64
1 ,, 6	= 10	3	= 78
1 ,, 4	= 15	2	= 114
12	= 25	1	= 184
11	= 30	0	= 1024
10	= 33		

EXPERIMENT XX.

The same iron foot of armature ABCDEF (Fig. 38) I next suspended transversely, so that the larger plane surface ABCD faced the pole of the magnet. That part of the iron which hung directly over this pole, was much thinner in the present experiment than the other part in the preceding experiment. From this arrangement the following results were obtained:—

* In the original, plate XI., fig. 4.

Distances in Inches & Lines.		Grains.	Lines.		Grains.
4 ,, 0	=	0	7	=	40
3 ,, 10	=	1	6	=	54
3 ,, 5	=	1¼	5	=	69
2 ,, 3	=	2½	4	=	79
1 ,, 10	=	4	3	=	86
1 ,, 2	=	15½	2	=	134
12	=	20	1	=	214
10	=	30	0	=	574
9	=	37			

EXPERIMENT XXI.

I next proceeded to ascertain in what manner the magnet acted upon iron filings; for which purpose I took an iron capsule of the same form and size as the magnet which I had used in the third experiment. The metal of the capsule was exceedingly thin, and commonly called Blick; this I completely filled with iron filings; and upon weighing it, found it possessed of less gravity than a magnet of the same size; inasmuch as filings do not form a compact mass. The difference in the weight was 15 drachms. The capsule was now suspended from the beam, and the same round magnet which I had used in experiment 3, was placed immoveably upon the table with its pole looking upwards as in the manner mentioned in experiment 3. On pursuing my observations as before, and ascertaining the attractive forces by means of weights, I arrived at the following results:—

Distances in Inches & Lines.		Grains.	Lines.		Grains.
9 ,, 0	=	0	7	=	115
4 ,, 9	scarcely anything		6	=	135
4 ,, 0	=	1	5	=	158
3 ,, 3	=	6	4	=	166
12	=	63	3	=	221
11	=	68	2	=	275
10	=	77	1	=	373
9	=	82	½	=	460
8	=	103	0	=	650

EXPERIMENT XXII.

The next thing I did was to pour out some of the filings from the

capsule, until it reached the same thickness as the solid mass of iron which was of the same weight as the magnet. The experiment furnished the following results:—

Lines.		Attractions measured by Apothecaries Grains.	Lines.		Attractions measured by Apothecaries Grains.
12	=	59	5	=	149
11	=	62	4	=	182
10	=	72	3	=	221
9	=	78	2	=	275
8	=	94	1	=	415
7	=	108	½	=	460
6	=	134	0	=	710 and even 772 at other points of contact in the same capsule.

Having made these observations, it may be well to compare the experiments one with another, to educe the consequences thence resulting, and to arrive at some useful conclusions, as far as we safely can.

Corol. 1. It is very evident then, that the magnet attracts the iron with greater force than it attracts another magnet; for in the fourth experiment both magnets, when in contact with each other, exercised a force of attraction amounting to 128 gr. But in experiment 16 the same magnet at the point of contact attracted the iron with a force of 180 gr. Consequently the iron was attracted with a greater force than the magnet. This is much more clearly shewn in experiment 17; where the same magnet, at its point of contact with the iron of lesser form than in experiment 16, had a force of attraction = 720 gr., which is more than five times greater than 128 gr. in experiment 4. Nay further, it affords additional confirmation to experiment 5; for in the latter case the round magnet NO, at the point of contact, attracted the other with a force of 340 gr.; but in experiment 18 the same round magnet attracted the iron with a force of 1312 gr.; in experiment 19 it attracted the iron with a force of 1024 gr.; and in experiment 20 it attracted the iron with a force of 574 gr. From various experiments therefore it is very evident, that the magnet attracts iron more strongly than it attracts another magnet. By this observation I am confirmed in the opinion mentioned in Chap. I., namely, that magnets which attract themselves by amicable poles do also at the same time repel each other; but the repulsion is overcome by the attraction. In like manner, magnets, when receding from each other by opposing

their hostile poles one to another, are nevertheless at the same time attracted; but the attraction is overcome by the repulsion. For how could the iron, which just before had been taken out of the fire and which was not impregnated with any, or at least with very little, magnetic virtue, be attracted by the magnet more strongly, than an excellent magnet endowed with attractive force? except it be for the reason, that the iron was attracted but did not at the same time repel; or if it repelled, repelled but little.

Corol. 2. In these attractions of the iron toward the magnet, there is a maximum and a minimum; for a mass of iron of a determinate magnitude and form will be attracted by a magnet of a determinate magnitude. Another mass of iron greater or less will be less attracted by the same magnet; and the more the several masses differ, either by excess or deficiency, from the mass which is most strongly attracted, the less also will they be attracted. This seems to be proved in experiments 18, 19, 20, in which was used the same round magnet NO, as in Fig. 26, p. 250; for in experiment 18, a mass of iron of intermediate magnitude was attracted, at the point of contact, with a force of 1312 grains. The iron parallelopipedon however which was much heavier, and was used in experiment 17, was attracted with a force of only 720 gr., and consequently less than the iron used in experiment 18. But the smaller mass of iron, which was used in experiment 19, was thicker than the iron used in experiment 20, which consequently when in contact was attracted with a force 574 gr. In order to afford a further confirmation of this result, I suspended from the beam a piece of iron which was much smaller; namely, the steel pyramidal foot of a common compass, the sharp point of which, when in immediate contact with the pole of the round magnet, was attracted with a force of 20 gr. I then changed the position of this steel foot, so as to touch the same pole of the magnet with its obtuser end; and in this case it was attracted with a force of 224 grains, and consequently much more powerfully than any of the iron used in experiments 17, 18, 19, 20. This result is further confirmed by the two experiments made with the iron filings, as in cases 21 and 22; for the larger quantity of filings was attracted at the point of contact with a force of 650 grains, and the smaller quantity with a force of 710 grains. But a much smaller quantity of filings left in the capsule was attracted with a force of 315 grains; whence it is manifest, that there is a determinate dimension of iron upon which the magnet acts with the greatest force, and that upon any larger or smaller mass of iron it operates with a less degree of force.

From these experiments may, I think, be elicited the best method

of arming a magnet so as to enable it to lift the greatest weight. We have only to ascertain by weighing, what is the mass of iron upon which it acts with the greatest force; and then to make an armature of the given thickness. From this corollary likewise it follows, that the magnet does not attract the iron with a force like that of the general law of attraction, and by which all bodies attract one another; for supposing that in equal particles of iron there is innate the same force of attracting the magnet, then the degree of attraction in the mass of iron is as the magnitude of the mass, and therefore a larger mass ought to be attracted by the magnet more strongly than a smaller. But the experiments shew the result to be very different, and that a larger mass is attracted more feebly than a smaller; whence we infer that the action of the magnet arises from a cause different from that of the universal law of attraction; as I will endeavour to shew more at large in the sequel.

Corol. 3. The magnet does not act upon iron at the same distance as two magnets act upon each other. For on referring to experiment 1 we find that the larger round magnet operated upon the smaller at a distance of 5 inches and 10 lines; in experiment 2, at a distance of 9 inches; in experiment 3, at a distance of 12 inches; in experiment 5, at a distance of 18 inches; but in experiment 18, the same magnet acted upon the iron at a distance of only 3 inches and 10 lines, as also in experiment 19 and 20; and at 4 inches in experiment 21. From these experiments we derive abundant evidence of our corollary. Being however desirous of obtaining further confirmation, I took a rotatory needle, commonly called a mariner's needle, which had not been rubbed upon the magnet; and observed at what distance from the magnet it began to be rotated by the magnet: I next rubbed the needle against a magnet, till it became impregnated with magnetic force like the magnet itself. This needle when replaced upon its pivot, turned from its position, at a distance of 4 feet from the round magnet NO; while in the former case, it would not turn when at a distance of only 9 inches. This corollary therefore is sufficiently demonstrated; it is also evident that a magnet emits out of itself a force to a greater distance than pure iron does; and that the latter eradiates its forces to a greater distance after it has touched the magnet.

Corol. 4. These experiments have all been instituted with a view to ascertain the proportion between the attracting force of the magnet and the distances. If now we cast our eyes over experiment 17, going on from the distance of 12 lines to that of 3, we shall observe that the numbers which express the degree of attraction are almost in the inverse ratio of the distances; but that from this proportion the attractions observed at smaller and greater distances deviate; for if we begin our

calculation from the distance of 12 lines, and thence proceed to a smaller distance, we shall find the consecutive numbers to be in the inverse ratio of the distances.

Distances in Lines.		Numbers from Calculation.		Ditto from Observation.	Distances in Lines.		Numbers from Calculation.		Ditto from Observation.
12	=	35	..	35	7	=	60	..	66
11	=	$38\frac{1}{11}$	..	37	6	=	70	..	76
10	=	42	..	43	5	=	84	..	96
9	=	$46\frac{2}{3}$	..	47	4	=	105	..	109
8	=	$52\frac{1}{2}$	..	57	3	=	140	..	131

Were it the case that in the other distances the numbers arrived at by computation, agreed, as accurately as these, with the numbers which are furnished by observation, I should not hesitate to affirm that the forces of the magnet which attract the iron were in the inverse ratio of the distances; for the small discrepancy between the two classes of numbers, as furnished the one by computation, the other by actual observation, would not stand in the way of our instituting this as the real proportion. For all physical experiments are of such a nature as seldom to correspond exactly with the results of calculation. But we find that in the smaller distances, there is much less agreement between the calculations and observations; for if we continue the previous proportion, the attraction at the distance of 2 lines ought to be 210 gr., and yet it was only 179 gr.; at the distance of 1 line, it would be 420 gr., and yet it was observed to be only 231 gr.; at the distance of $\frac{1}{2}$ line, it ought to be 840 gr., when yet it was only 343 gr. Now whence does this discrepancy arise? is it that, use what iron we may, it possesses a certain power of repelling the magnet; and which, when diffused only to a small distance, takes away a certain portion of the attraction upon which at a still greater distance there is no repulsive force to operate? or does the repulsive force of the magnet itself give rise to this inequality of attraction?

The other experiments, namely, 16 and 18, I likewise took under consideration, with a view to ascertain whether, at the distances of from 12 to 3 lines, there was any attraction in the inverse ratio of the distances; but in these cases I did not find the numbers obtained by computation so nearly approximating to those supplied by observation. The following are those obtained by observation in experiment 16, compared with those derived from computation:—

Distances in Lines.		Numbers from Calculation.		Ditto from Observation.	Distances in Lines.		Numbers from Calculation.		Ditto from Observation.
11	=	14	..	14	5	=	$30\frac{4}{5}$	..	44
10	=	$15\frac{2}{5}$	..	16	4	=	$38\frac{1}{2}$	..	52
9	=	$17\frac{1}{5}$	..	17	3	=	$51\frac{1}{3}$	..	72
8	=	$19\frac{2}{5}$	..	21	2	=	77	..	96
7	=	22	..	29	1	=	154	..	110
6	=	$25\frac{3}{5}$	..	32					

The attractions observed from line 11 to 1, are greater than those indicated by the calculation; but at the distance of 1 line they are less: an anomaly which arises doubtless from the attracting and repelling force, both of which act simultaneously upon the iron, and disturb the constancy of the proportion. The following however are the numbers obtained from experiment 18, according to the inverse ratio of the distances; in which the same anomaly occurs.

Distances in Lines.		Grains from Calculation.		Ditto from Observation.	Distances in Lines.		Grains from Calculation.		Ditto from Observation.
12	=	61	..	61	6	=	122	..	164
11	=	$66\frac{6}{11}$	..	70	5	=	$146\frac{2}{5}$	..	201
10	=	$73\frac{1}{5}$	..	84	4	=	183	..	229
9	=	$81\frac{1}{3}$	..	106	3	=	244	..	285
8	=	$91\frac{1}{2}$	..	121	2	=	366	..	361
7	=	$104\frac{4}{7}$	..	140	1	=	732	..	472

As far then as I may be allowed to form a conjecture, it may be said that the forces of magnets, which mutually attract and repel each other, are in the inverse ratio of the distances, or in a proportion very near; and inasmuch as the magnets attract and repel each other simultaneously, the experiments recorded in Chap. I. cannot but give the numbers which express the attraction in an inconstant proportion; since they by no means represent the attraction alone, or the repulsion alone; consequently the forces of the magnets do not decrease in so great a proportion as the duplicate or triplicate ratio of the distances, as some have thought.

Corol. 5. Moreover from the foregoing experiments we collect, that the attraction of iron toward the magnet is not in proportion to the magnitude of the surface opposed to the magnet, but that here also we meet with a maximum and minimum. For in experiment 19, the surface F of the foot of the armature was turned to the magnet, see Fig. 38, p. 295: the other surface of the iron, both superior and inferior, not including the sides, was but small; yet the attraction took place at the

same distance from the magnet, as in experiment 20, in which the surface of the iron ABCD which was opposed to the same magnet, both superior and inferior, was as much, nay, considerably more than twelve times larger. At nearer distances, however, the same iron which was used in experiment 19, was attracted much more strongly than in experiment 20; as may be seen from a comparison of the tables; in which we observe, that the smaller surface of the iron was attracted with greater forces than the larger. Still we cannot hence infer that the smaller the surface of the iron which is opposed to the magnet, the greater is the attraction; for I have adduced other experiments, made with the iron foot of the compass, which shewed the attraction of the pointed end of the iron toward the magnet, to be smaller than that of the obtuse end. Wherefore there must be a surface of a determinate magnitude, and of a determinate mass of iron, which will be the most attracted by the magnet; while the other superficies, both larger and smaller than this, will be attracted the less. From these experiments might be adduced various corollaries; but it will be better perhaps to mention only those which are the most evident, and are established by numerous observations, rather than such as flow only from some one or other particular observation.

Scholium. So far as I am aware, Mr. Hawksby was the first person who instituted an enquiry into the proportion of the magnetic forces at various distances of the magnet from the iron. The method he adopted, which was very different from ours, although it might not meet with the approbation of all, still deserves to be known, on account of the effects observable in adopting it. The description of it is to be found in the *Philosophical Transactions*, No. 335, page 506; or in the *Compendium*, vol. 4, part ii., page 295.

This highly mechanical genius took a quadrant, the radius of which was 4 feet; this he placed upon the ground, and in the centre of it a rotatory needle. This needle, when left to itself, stood in the quadrant at 0 deg. He then placed a magnet in a piece of wood; so that its pole lay in the same plane with the quadrant and the needle, and might be moved round the margin of the quadrant from one degree to another, and from one distance to another. The magnet was of an irregular figure, and weighed about 6 lbs. He made however the experiments with two needles; one of which was 3 inches long, the other 6 inches; but he always found the shorter to be the better.

In the tables containing these experiments, we must observe, that the longer needle, at a distance of 9 inches, formed with the magnet an angle a little larger, than the shorter needle, at a distance of 3 inches. The shorter needle, at a distance of 9 inches, made an angle

9 deg. less than the longer at the same distance. These paradoxes, however, will be easily understood, if we consider the disproportion in the length of the needle; for the point of the longer needle, at a distance of 9 inches, was nearer the magnet by one inch than the point of the shorter; and the point of the shorter needle, at a distance of 9 inches from the magnet, was distant 5 inches more than the point of the larger needle, when the magnet was in the same degree of the quadrant. This disproportion therefore must be borne in mind. We must moreover observe, that the magnet, at the distance of 5 inches from the needle, made an angle of 2 degrees with one needle, and of $2\frac{1}{2}$ degrees with the other needle; but at a greater distance the change in the needle was not observable; so that the magnetic force extended itself to a distance of 5 feet, at which the proportions could be taken; but at greater distances the force of the magnet was so feeble, that no observation could be taken with certainty.

SHORTER NEEDLE.

Its distances from the Magnet in Inches.	Angles made by this Needle at the several distances in Degrees & Minutes.	Differences.
3 ..	87 „ 0 .	180
6 ..	84 „ 0 .	330
9 ..	78 „ 30 .	570
12 ..	69 „ 0 .	735
15 ..	56 „ 45 .	795
18 ..	43 „ 30 .	630
21 ..	33 „ 0 .	540
24 ..	24 „ 0 .	360
27 ..	18 „ 0 .	270
30 ..	13 „ 30 .	150
33 ..	11 „ 0 .	135
36 ..	8 „ 45 .	105
39 ..	7 „ 0 .	90
42 ..	5 „ 30 .	60
45 ..	4 „ 30 .	40
48 ..	3 „ 50 .	30
51 ..	3 „ 20 .	20
54 ..	3 „ 0 .	15
57 ..	2 „ 45 .	15
60 ..	2 „ 30 .	0

LONGER NEEDLE.

Its distances from the Magnet in Inches.	Angles made by this Needle at the several distances in Degrees & Minutes.	Differences.
9 ..	87 „ 30 .	345
12 ..	81 „ 45 .	570
15 ..	72 „ 15 .	1137
18 ..	53 „ 20 .	1100
21 ..	35 „ 0 .	660
24 ..	24 „ 10 .	380
27 ..	17 „ 50 .	280
30 ..	13 „ 10 .	180
33 ..	10 „ 10 .	130
36 ..	8 „ 0 .	90
39 ..	6 „ 30 .	75
42 ..	5 „ 15 .	65
45 ..	4 „ 10 .	40
48 ..	3 „ 30 .	30
51 ..	3 „ 0 .	25
54 ..	2 „ 35 .	20
57 ..	2 „ 15 .	15
60 ..	2 „ 0 .	0

Now inasmuch as in these experiments we are unable to see with accuracy the distances of the magnet from the needle, the Royal Society requested the celebrated Mr. Brook Taylor to institute experiments relative to the magnetic forces in another and a clearer manner; hence this sagacious and eminent mathematician placed a needle in the centre of the former quadrant; and the magnet, the axis of which lay in a horizontal plane, he moved backward and forward from the needle in a line which was at right angles with the natural direction of the needle. Then measuring the distances by a line between the centre and the magnet, he was enabled to form the following table :—

Distances in Feet.	Variations of Needle in Degrees & Minutes.	Distances in Feet.	Variations of Needle in Degrees & Minutes.
1 ..	81 ,, 45	6 ..	5 ,, 35
2 ..	58 ,, 0	7 ..	3 ,, 30
3 ..	30 ,, 0	8 ..	2 ,, 20
4 ..	16 ,, 0	9 ..	1 ,, 35
5 ..	9 ,, 20		

These experiments were made with a most excellent magnet belonging to the Royal Society; but inasmuch as in these cases there was not preserved a similar position of the line in which the magnet was moved toward the needle, though it was an indispensable requisite, we cannot in these cases form much of a conclusion; as indeed Whiston observes; who therefore undertook the task of additional experiments. Indeed I think that by none of these methods shall we attain our object; as will be evident from the suggestion I shall have to make after noticing the observations of Whiston. The experiments of this very clever philosopher I have thought it worth while to adjoin; because they were made with a magnet and iron first impregnated with a magnetic force. This investigation therefore was conducted in a manner altogether different from our own; inasmuch as I used either two magnets, or a magnet and pure iron unimpregnated with any magnetic force. Whiston took two mariner's needles, balanced on their pivots; one of which was $4\frac{1}{2}$ inches, and the other 4 ft. long; also a spherical magnet of the diameter $2\frac{6}{10}$ inches. The south pole of this magnet he always opposed to the northern points of the needles, by moving the magnet toward the needle in such a manner that the latter formed a right angle with the directive line of the magnet. He then measured the chords of the arcs in which the needle declined from its natural direction; the lengths of which he assumed as the quantities to express the attractive forces. Instead of the chords he substituted sines, which are the half of the chords; and then he arrived at the following results :—

Distances in Inches.	Degrees of Declination.	Sines of Half the Arcs.	Distances in Inches.	Degrees of Declination.	Sines of Half the Arcs.
3	0	0	27	2	174
6	0	0	30	$1\frac{1}{6}$	160
$6\frac{1}{2}$	90	7071	33	$1\frac{1}{3}$	131
9	27	2334	36	$1\frac{1}{4}$	109
12	13	1132	39	$0\frac{5}{6}$	73
15	$9\frac{3}{4}$	848	42	$0\frac{3}{4}$	65
18	$6\frac{3}{4}$	588	45	$\frac{2}{3}$	58
21	$4\frac{1}{2}$	392	48	$\frac{1}{2}$	44
24	3	262			

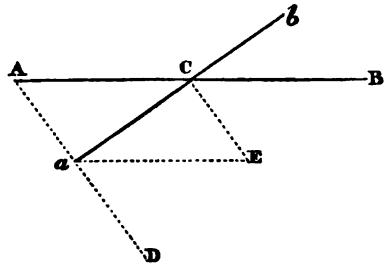
Let us now attend to the numbers which represent the distances and the sines which correspond to them; *e.g.* the sine 2334 answers to the distance of 9 inches, and the sine 588 to the distance of 18 inches. These numbers expressing the sines are one to the other exactly as $3\frac{8\,5}{9\,4}$ to 1, or nearly as 4 to 1; that is to say, in the inverse duplicate ratio of the distances. The sines answering to the distances 12 and 24 are 1132 and 262; which are one to another, as $4\frac{4\,3}{1\,3\,1}$ to 1; consequently these are reciprocally to each other in a greater proportion than the former. The sines answering to the distances 15 and 33 inches are 848 and 131, which are to each other as $6\frac{6\,3}{1\,3\,1}$ to 1. The sines answering to the distances 18 and 36 are 588 and 109, which are as $5\frac{4\,3}{1\,0\,9}$ to 1. The sines answering to the distances 21 and 42 are 392 and 65, the proportion of which is $6\frac{2}{6\,5}$ to 1.

From the foregoing account it appears to be inferrible, that the proportion is exceedingly inconstant; being sometimes less than a duplicate proportion, sometimes a little greater, sometimes much greater. Whiston however alleges that the ratio which obtains is the sesqui duplicate; since in experiments of this kind a perfect geometrical exactitude cannot be obtained. And this indeed we should grant, were the allowance required for this inexactitude not too great; as appears here to be the case; for the discrepancy is too considerable, since the experiments in one case give the proportion of $3\frac{8\,5}{9\,4}$ to 1, and in the other case of $6\frac{6\,3}{1\,3\,1}$ to 1; so that these two must be reckoned as one and the same proportion. I do not see therefore why we should not confess that no constant proportion obtains, rather than strain the experimental results to discover the existence of a proportion where nature denies it.

In pursuing however this method of ascertaining the magnetic forces, there is latent a difficulty. For the magnet or the needle is acted upon

by two forces distinct from each other; the one attractive, the other directive toward certain poles of the earth. In the present experiment the needle is operated upon by a force directing it to these poles. When the magnet is held to the needle at different distances, and deflects it from its previous direction, then by its attractive force it acts upon the directive force of the needle and deflects it; until the directive force, which acts upon the oblique position of the needle, finds its equilibrium with the attractive force of the magnet. Consequently we cannot, under these circumstances, detect the quantity of the forces in the magnet and needle mutually attracting each other; but only a something very different. For let us conceive a rotatory needle fixed upon its pivot, placed in the middle of any current of water, and observing a direction conformable to that of the current; let us also conceive that the point of the needle is, by means of a string attached to it, drawn sideways toward the bank in such a manner that the rope is always perpendicular to the needle; in this case, if the direction of the needle be made angular, not only does the string, drawing with power, act upon the needle, but also upon the current; and has to overcome the force of the current running against it sideways and propelling it in a right line according to the determination of its course; the force of the incursion of the stream being the greater in proportion to the opposition of the direction of the needle to the current of the stream. The force drawing and inflecting the needle acts here, therefore, upon the needle and upon the directive course of the current at the same time, and not upon the needle alone; inasmuch as it is now only a body to be moved. In like manner a rotatory needle, rubbed upon a magnet, is driven by the universal directive force toward the poles of the earth; and upon this directive force as well as upon the needle, the magnet in our experiment acts with its attractive force; just as in the instance above cited, the power by means of the intermediate string draws the needle in the stream. It is with this directive force that the magnet acts upon the equilibrium at different distances, and at the variously oblique positions of the needle. From these experiments consequently we cannot infer the degree of force with which two magnets are made to approach one to another, or a magnet to a needle and to iron, solely by the attractive force. Still these experiments are not without their utility; because, supposing the needle capable of turning upon its pivot without friction, they shew that the attractive force of the magnet acts upon the directive force, at stated distances, according to the ratios above exhibited; and when the attractive force of a magnet is known, then we may ascertain the quantity of directive force at any angle of the needle's obliquity,

Fig. 39.*



by the common rules of mechanics. Thus in Fig. 39, let ACB be a needle whose axis is in C; which, by the action of the directive force in the line BCA, is kept in the same determination. Suppose the needle to be drawn by a force D, into the oblique position *a*C*b*, so that the angle C*ab* is a right angle. Let any straight line E*a*, be drawn parallel to ACB, which indicates the directive force; and let EC be drawn perpendicular to *a*C. Let the directive force be conceived to be resolved into one perpendicular to the needle, or EC, and into another *a*C; then EC will be directly opposite to *a*D, the direction of the power D; and the three sides of the triangle E*a*C will by their magnitudes express the forces which we find here. CE will denote the force of the drawing power D; E*a* or AC the whole of the directive force; and *a*C part of the remaining directive forces. The length of the needle therefore *a*C being known, as also the angle EC*a*, and the quantity of the attractive forces or EC, then E*a* or AC is found, that is to say, the quantity of the directive force.

In the course of my reflections upon the universal directive magnetic force, by which the needle is directed and depressed below the parallelism of the horizon in these regions of Europe, as will afterwards be evident when I come to treat of the inclination of the needle, I began to doubt whether in the experiments in which I had suspended one magnet above the other, from the beam, there might not have arisen a certain depression of the magnet toward the horizon by reason of the universal directive force, and whether the exact admeasurement of the attractive forces might not thus be disturbed. My doubts however vanished upon considering, that the directive force thus depressing the magnet produced, as it were, a certain portion of the gravity of the magnet; and inasmuch as this force, together with the gravity, was brought by weights into a state of equilibrium before the experiment was begun, and always remained equal, it could not possibly have disturbed the observations that were made in regard to the attractions.

* In the original, plate XII., fig. 6.

CHAPTER VII.

ON THE INFLUENCE OF THE MAGNET UPON IGNITED IRON.

A PRIORI OR FROM FIRST PRINCIPLES.

The magnet operates with less power upon iron red hot [candefactum] *or ignited, than upon cold iron; and its influence upon ignited iron diminishes in proportion to the greater degree of ignition.* The actives themselves, which constitute the bright and living fire, can in no way impede the fluxion or gyration of the magnetic element; as will be shewn in our theory of the fourth and fifth active. For the fire, which is luminous and acts by flame, consists in the motion of actives highly compounded; which in the volume of the particles of the most subtile magnetic element are capable of perfectly performing their gyres without restraint or retardation; just as masses can, or highly compound bodies, in the air or ether. Of this however we shall treat in the sequel. Meanwhile we premise that neither the flame of fire, nor heat, can possibly interfere with the gyration of the vorticles or effluvia: all that it does is to induce, by reason of the ignition, a motion of the parts of the iron. For as we have already stated, the conjunctive force of the iron and magnet consists in this; that the magnetic force is capable of travelling from its own sphere into the iron, in a state of regularity; so that the iron can have all its individual parts kept within the same current; which supposes a state of rest among the parts themselves. If however the parts are in a state of interior motion and perpetual transference from one place to another, or from one position to another, it cannot be surprizing if also the

sphere of the vorticles which penetrates the iron cannot so fixedly and so firmly keep the several parts attached to itself; and if, instead of parts which are at rest, it should assign to itself such as are mobile, and so should act not upon a firm and steady but upon a moveable compages; in which case the magnetism comes to be diminished in proportion to the degree of ignition. We may see what is the state of red hot iron, when watching a melted mass poured fresh from a furnace in a smelting-house. In one place we perceive little rivulets running, and glomerated volumes of *scoriæ*, or parts that but little resist the igneous action. In another may be seen bursting forth extremely white or blue sulphurous flames; in another living fountains and torrents of sparks vibrating one around the other and darting out into the air; so that the whole mass is interiorly in the highest commotion; for the fire lives in its very inmost parts, or in veins of the most diversified natures; there being in iron parts of different kinds, one that melts and boils, another that separates into pieces, burns, and consumes. These, when glomerated into one body, are condensed; so that as the poet sings,

Æstuat clausis rapidus fornacibus ignis.

In fine, since the action of the fire is destructive of the innermost fabric, thus disturbing the interior parts of the iron and hurrying them from place to place, we are not to wonder if the magnetic sphere which penetrates the iron should have to arrest and detain not parts which are fixed, but which are free and in motion; which, if they flow with perfect facility, cannot cohere with the sphere of the magnet; the particles eluding and as it were shunning the magnetic force and connectedness. Whence consequently the magnet is no longer able to attach them to itself, as it can in the case of cold iron; the parts however which actually become affixed to the magnetic sphere and current, adhere to it according to the degree of ignition.

A POSTERIORI OR FROM EXPERIMENT.

EXPERIMENT XXIII.

An iron parallelopipedon, weighing 5 lbs., was placed in a brazen

scale which was suspended by chains of brass attached to the beam of a balance, and was brought into equilibrium by weights placed in the opposite scale; after which it was submitted to a strong fire until it grew red hot, but not so as to emit sparks. It was then replaced in the scale, beneath which the larger spherical magnet NO (Fig. 26. p. 250) was placed at a distance of exactly 2 inches; upon which the ignited iron was immediately drawn down by the magnet. The attractive force was then investigated, by placing weights in the other scale so as to restore the equilibrium. During the progress of cooling, the attraction of the magnet more and more increased, reckoning from the period of the utmost degree of heat down to that in which the hand could scarcely endure contact with the iron, when the attraction became equal to 3 grains; but on the iron continuing to cool down to the same degree of temperature with that of the atmospheric air, the attraction further increased by 4 grains; so that the whole difference of attraction intervening between the greatest degree of heat and the atmospheric temperature, was, at the distance of two inches, equal to 7 grains; while the attractive force of this magnet, as exerted upon the same iron when cold, was equal to 16 grains; which had consequently decreased to almost half, when the iron was at its highest degree of heat. After this the experiment was repeated with the same magnet and iron, but only at one inch distance. The iron, which as yet was cold, was attracted by the magnet with a force of 61 grains; but when heated to its highest degree, with a force of 26 grains; so that the difference of attraction was 35 grains. In this experiment the iron was hotter than in the former, and the force of the magnet therefore had here decreased. Should these operations appear to any experimentalist to be too laborious, we shall demonstrate by a more easy method, that the magnet does not attract or sustain red hot iron so much as cold; for whether it be armed or unarmed, in case as much weight of cold iron be attached to it as it can just lift, if the iron be afterwards heated and applied, the magnet cannot sustain it.

It was formerly observed by the celebrated Boyle, that a magnet did not operate upon another magnet ignited, with as much force as upon another that was cold. He kept three magnets of compact substance in the fire, until they had become red hot; he then put them upon a lamella of silver; next, placing beneath them another magnet, the latter attracted the ignited ones, yet very feebly, and the attraction continually increased, in proportion as the magnets became colder.

I cannot therefore pass over in silence the error of Kircher, who in book i., § 31, p. 140, affirms, with respect to the magnet, that the operation of the magnet upon iron cold and iron ignited, is precisely the same. This great man appears to have fallen into this error in con-

sequence of conducting his experiments in too rough a manner, by applying the ignited iron only to an armed magnet; in which case it is indeed attracted, but never so strongly as iron in a perfectly cold state.

May we not hence understand, how it is that the magnet attracts iron, impregnated with a summer temperature, with less force than when it possesses a winter temperature and is more condensed; as I have noticed in experiment 3?

In Chap. V. of this dissertation it will be shewn, that all iron is impregnated with a magnetic force, when it is made to cool; also in Chap. III., that fire expels the same force, or a still greater, communicated from the magnet to the iron. Consequently iron in the whitest heat, and deprived of a great part of its attractive virtue, cannot be attracted by the magnet with as great an impetus as cold iron endowed with a magnetic force. Besides, the vibratory motion with which the ignited parts of the iron are contremiscent, impede the magnetic forces, and render them inefficient. We might here further enquire, as to the manner in which the fire operates upon these forces; but inasmuch as I have not yet explained the manner in which these forces are acquired, whether they are corporeal or whether they are of a different character, it may be well at present to say no more on this part of the subject, but rather first to employ ourselves in investigating these forces.

CHAPTER VIII.

THE QUANTITY OF EXHALATIONS FROM THE MAGNET, AND THEIR PENETRATION THROUGH HARD BODIES, ETC.

A PRIORI OR FROM FIRST PRINCIPLES.

The magnetic sphere is capable of flowing freely not only through volumes of the elements, such as air and ether, but also through water and flame; as in like manner through hard bodies, whether of wood or of stone. The magnetic element inasmuch as it is the most subtile and the first, permeates, with a current perfectly uninterrupted, the interstices of every succeeding and grosser element. For both the ethereal and the aërial particles are surrounded and pressed by them on every side, and are thus kept in their figure, situation, and motion. The crassest waters are surrounded by ethereal particles, which are enabled to perform their fluxions and gyrations through the interstices of these waters naturally and unretarded. They can likewise permeate flame, which consists of the actives of the fifth element. But upon this subject a clearer idea will be conveyed in the third part of our *Principia*, where we shall also furnish the theory of each element. It will be sufficient here to state by way of anticipation, that these are the first and therefore the most subtile elements in the mundane system, and consequently can flow with a perfectly free course around the larger elementary particles, which are hence derived; and consequently also through the texture of harder parts, such as stones and metals; for since these can be penetrated not only by the ether, by hot water, by different kinds of menstrua, by

salts and mercury, much more may they be penetrated by the minute volumes of the most subtile element which surrounds the subtile ether or occupies the spaces between the particles of ether. With regard to the spaces between the compaginated parts of metals and stones, the reader is referred to those authors who have attested the fact on the ground of innumerable experiments. No one therefore can deny, that these spaces open wide enough to receive the element of which we are speaking, which is most subtile; especially when we consider that it fills the spaces between the particles of ether, as also the ethereal and aërial spaces in every individual particle, and that the ethereal particles are themselves of such a nature as to be capable of permeating the pores and meatuses of harder bodies.

Nor do the effluvia which permeate the texture of harder bodies anywhere lodge, impinge against, or become affixed to, any of their parts or parietes; but flow with perfect freedom throughout the entire mass, without contaction, occursion, or incursion. For the effluvia lie enclosed within their own vorticles; since they are composed of centres, and a centre cannot pass out of its own vorticle, or beyond its own peripheries; and without a vortical gyration, it never flows at all; hence it cannot run or strike against any parts of a hard body; for the circumfluous motion of a vorticle defends from any incursion or conflict its own central effluvium: wherever a vorticle runs, there also follows the effluvium or centre: wherever the vorticle is repelled there also is repelled the effluvium; from every hard part the effluvium is kept at a distance by the vorticle; thus does it reside in its centre, free from every casualty, so long as its motion remains in the vorticle: hence it cannot strike against or become fixed to any paries: nor can it come into conflict with effluvia of any other kind; but inasmuch as the element is permeable, so also it follows is the effluvium itself.

2. *Nor can the magnetic sphere conjoin with itself any other kind of metals besides iron and steel, or such as participate of iron;* for the magnetic sphere can operate only upon such bodies as are similar to itself and possess a similar motion among similar elementary particles. Now in metals of the various kinds, there occur no where effluvia similar to those which are

in iron, which throng the interior texture of its parts, and occupy also the space around it to some distance; whence at its own pleasure the magnetic sphere can turn them into the direction of its own current, either in whole or in part.

8. *By a larger quantity of emanating effluvia, the magnetism and conjunctiveness of bodies are augmented.* For the larger the quantity of effluvia that emanates, the more vorticles are there and spiral gyrations to flow round about; and the more numerous are these, the more strongly do they become fastened together by spires of greater curvature, and thus the stronger also is the magnetic sphere, according to the theory already premised; so that what principally contributes to the magnetic force, is the quantity of effluvia, which never in any respect destroys or enfeebles the connective power.

Still however there is no need that a wave or tide of effluvia should perpetually emane from the magnet; so that the magnetism should be renovated and restored by a continual influx and efflux of effluvia. For the sphere itself is capable of subsisting around the magnet without any considerable quantity of effluvia, or any considerable additional supplies; since the magnet floats in its own sphere, and constitutes, together with its sphere, as it were one contiguous body. The sphere itself remains attached to the magnet by the gyrations of the individual parts, or by vorticles. Those effluvia only are capable of escaping from the sphere which are the more remote, and whose vorticles are not colligated with the adjacent at an angle of 45 degrees. Now since a sphere thus formed and having its parts reciprocally held together, cannot stray from its own magnetic body, it follows that there is no necessity for the magnetism to become constantly renovated by any new and considerable wave of effluvia.

4. *Iron cannot acquire by friction against a magnet any augmentation of weight; but the smallest parts which become perforated in a right line, and are partially loosened* [demisolutas] *by the friction of the magnet, are only made transverse and put into a regular site: and thus it is that magnetism is communicated to iron; whence the magnet experiences no loss of its forces, since one magnet alone would suffice to render magnetical all the iron in the world*; as is evident from what we have already said, and as will further appear in the sequel.

5. *Whoever wishes to form and systematize principles by geometrical and mechanical rules, and afterwards to confirm them by experiment, must not employ himself in assuming and refuting the opinions and arguments of others; but must only present to notice causes, and demonstrate the connexion between first principles and experiments.* Unless there be a geometrical and mechanical connexion between first principles and actual experiments, then are these principles but mere hallucinations, mere dreams of the brain. If however there be this connexion, then will causes arrange themselves simultaneously according to this connexion, and all arguments and opinions to the contrary are thus neutralized and silenced; so that to employ ourselves in refuting them is only to spend our time and trouble to no purpose: they are sufficiently refuted of themselves, if the causes and their mutual connexions are demonstrated and acknowledged; in these it is that the truth consists; and truth is one and incapable of consisting in any other than its own proper order of connexion. Consequently wherever our talented author Muschenbroek, seems to impugn by arguments, however ingenious, the doctrine of the magnetism of effluvia, I can have no wish to oppose him; but shall here subjoin a literal quotation of his arguments; particularly since his opinion is so far also my own, that mere effluvia cannot of themselves present any magnetism; and would be entirely devoid of it, were it not for a circumfluous and vortical motion.

A POSTERIORI OR FROM EXPERIMENT.

EXPERIMENT XXIV.

Inasmuch as many of the learned have been of opinion, that the effects produced by magnets depend upon certain subtile effluvia continually emitted on all sides, or upon an ethereal fluid everywhere surrounding the magnets, pressing, or propelling the magnets one towards another, iron, or other bodies which are attracted by them, I have made it my business carefully to enquire into the arguments on which this opinion is founded; and upon investigation find that there appeared to be either none, or such as were so feeble that I might with justice be accused of rashness were I, without some better reasons, to

maintain that magnetic effluvia, or an ethereal fluid, was the cause of magnetic phenomena. After commencing my task and going in search of the aforesaid effluvia or ether, I could not meet with any experiments which could originate the slightest suspicion of their existence; while on the contrary, I became possessed of data which clearly convinced me that magnets are not governed, nor can be, either by effluvia or by ether. To make this clear, let us suppose that there are effluvia which proceed from the magnet, and which by their efflux are the cause of repulsion, and by their afflux, the cause of attraction; and let us imagine a magnet such as in Fig. 40, nicely suspended from a beam; and another magnet placed under it upon a table. From each of these let there be a free egress and regress, and let the magnets attract each other with their greatest force. Next let us conceive a solid and dense body interposed between them. Will not the effluvia of each magnet run against it? will they not be intercepted and determined in a different direction? and will not the attraction and repulsion consequently be removed? If it be rejoined that all bodies are exceedingly porous; that the effluvia are so extremely subtile as to be capable of easily permeating the pores; and that attraction and repulsion may in this case be observed equally as when nothing is interposed between the magnets; we reply, that we admit indeed that all firm bodies possess pores, yet still they are composed also of many solid parts, impenetrable, and hence interceptive of the effluvia which flow into them. The heavier that bodies are, the more solid are they and the less porous; whence they will consequently intercept much more of the effluvia of other bodies, however subtile the effluvia may be. All odours do not pass through the pores of glass, metals, stone, and other solid bodies. Light, which is the most subtile fluid we know, falls upon glass, metal, silex, water, oil, and every other body. A great portion of it is reflected from the solid parts; another portion passes through the pores; so that after its transit through transparent bodies, it is considered to be much rarer, not shining so brightly; and much rarer still is that which passes through the pores of more opaque bodies, in those cases in which it effects a transition. Is not a considerable portion of light intercepted by the atmosphere, by thin vapour, nebulæ, or extremely rare clouds? But the subtilty of fire perhaps does not much yield to that of light. Hold over it a very susceptible thermometer, and the mercury will be observed to become immediately rarefied. Between the fire and the thermometer place a piece of glass,

Fig. 40.*

* In the original, plate IX., fig. 2.

a lamella of metal, of paper, of wood, or any other firm substance; and by all these the fire will be intercepted. For at first the fluid will not ascend in the thermometer; then after a lapse of time it will be observed to be rarefied only slowly, and but little. Remove the interposed body, and the fire now conveyed to the fluid without any impediment, will suddenly rarefy it to a considerable degree. Even the most highly volatile spirit that art ever prepared, may be so confined in glass bottles as not to transude, or but little and slowly, through their pores: the air may be so enclosed within any solid body as either not at all or with difficulty to pervade its pores. In general it may be affirmed, that there is no kind of body known which may not wholly, or for the greatest part, be confined by metals, glass, or other solid substances. If therefore metals and other very solid bodies may intercept the particles constituent of odours, all volatile spirits, as also both fire and light, either entirely or for the greatest part, will they not in some measure intercept the magnetic effluvia in such a manner, that beyond the intervening impediment the effluvia will not be so plentiful as when the impediment is removed? Do these effluvia pass through the most solid bodies with the same facility as if nothing were there? No one, I think, who reasons from experiments compared one with another, or forms clear mechanical conceptions of bodies and their texture, can possibly adopt this opinion, which rejects all analogy, and assumes impenetrable bodies to be perfectly penetrable. We must therefore maintain, that if effluvia are perpetually emitted from a magnet and also attract another magnet or iron, these effluvia must be intercepted by some metallic, vitreous, or other perfectly solid body; and that one magnet could not then exercise upon another so great a power of attraction as if both were opposed to each other at the same distance without any intervening obstacle. If, however, both have the same power of attraction when there is an obstacle interposed as when there is none; then are there no effluvia, but the magnetic phenomena result from other causes. Let us therefore betake ourselves to experiments, and ascertain whether bodies the most perfectly solid, when placed between two magnets, take away, diminish, or in any wise alter the attracting forces, or whether they leave them entire.

1. A magnet H (Fig. 26, p. 250) was suspended from the beam, beneath which, at $1\frac{3}{4}$ inches, was placed the *terrella* NO; and an inquiry was then instituted into the quantity of the attracting forces. Between each magnet was interposed a mass of lead, rather broad but only $1\frac{3}{4}$ inches thick; in which case the attracting forces of the magnet remained the same as before. The lead was then removed, and again interposed as before; but the attraction always continued the same.

2. Instead of a piece of lead there was taken a parallelopipedon of tin 1¼ inches thick. When this was placed between the same magnets, no increase, decrease, or difference in the forces was observable. Nor could they be affected, even in the least, by the interposition of several globes of tin possessing a greater thickness; the forces remaining the same as if nothing was interposed between the magnets.

3. A mass of copper 1 inch thick and several inches wide being interposed, produced no change in the attractive forces; whether interposed or not, the attraction remained the same.

4. Coins of gold or silver interposed, produced no difference in the attractive forces.

5. Lest the thinness of the metals should be alleged as the true reason that the transmission of the magnetic forces was unimpeded, we took a parallelopipedon of lead 1 foot thick, as also a more powerful magnet than the one we had used in our former experiments. This magnet was placed upon a table, so that the other H suspended by a string might be made to descend, by the increase of the attractive forces. Yet even in this case, the attractive force was observed to be the same when the lead was withdrawn, as when it was interposed between the magnets.

EXPERIMENT XXV.

In the course of the foregoing experiments, I began to suspect whether or not the magnetic effluvium intercepted by the metals, did not spread itself along their surface; and whether after having reached their margins it did not inflect its course and surround the magnets, travelling equally upwards and downwards, and thus depressing the suspended magnet toward the inferior, the same as if no metallic body intervened. In order to satisfy myself upon this subject, I caused three metallic capsules to be made; one of lead, another of tin, a third of copper; which might enclose the magnet used in experiments 7 and 8. The magnet being then inserted into one of the capsules, the lid of the capsule was soldered down; by which means the stone was secured within the metal. The capsule was then suspended from a long cord annexed to the beam, as in the foregoing experiments; and on being lowered to different distances, was attracted by the forces exhibited in the following table. It is to be observed that the same magnets were employed as in experiment 7.

Distance of Magnet in Lines.		Its Attraction in the Leaden Capsule given in Grains.		Ditto in the Copper Capsule in Grains.		Ditto in the Tin Capsule in Grains.
12	=	57	..	57	..	57
11	=	62	..	63	..	63
10	=	66	..	65	..	66
9	=	70	..	70	..	71
8	=	79	..	78½	..	79
7	=	83	..	83	..	83
6	=	91	..	90	..	90
5	=	101	..	101	..	101
4	=	115	..	113	..	114
3	=	124	..	114	..	124
2	=	148	..	148	..	148
1	=	168	..	168	..	168

By comparing these three tables one with another, and with the one belonging to experiment 7, we perceive that there is a very great agreement between the attractions at equal distances. With regard to some of the numbers which exhibit a little discrepancy, and consequently represent some variation in the attraction, we must observe; that a magnet suspended by a cord can never, in such a variety of experiments, be so accurately manipulated as that the same points in the upper magnet shall always oppose the same in the lower; a circumstance which must necessarily originate some variation in the attraction. My wish however has been to exhibit faithfully the observations, together with all their anomalies, rather than to correct or to alter any; for if any one will but repeat the experiments, he will soon discover that, use what dexterity he may, he cannot always find at all distances the same reciprocal attraction between the magnets; because when, by the evolution of the string HG, the magnet H is in the slightest respect made to change its former position, another and a different attractive force toward NO is immediately observable.

From these experiments therefore it is evident, that metals do not retard the magnetic forces, nor diminish, nor disturb them; but that, in respect to magnetic effluvia, they may be what vitreous and transparent substances are in respect to light, and which transmit through themselves the largest quantity of light. It occurred to me therefore that similar experiments might be instituted with other solid bodies; which might be in the same relation to effluvia as opaque bodies are to light. With this idea I enclosed a magnet within a capsule of Chinese porcelain; and after this, in another capsule of glass; and in these two experiments the attractive forces were submitted to examination in the

same manner as in the preceding; but neither capsule offered any retardation to the magnetic forces, nor occasioned any decrease in them; inasmuch as the forces traversed each with the same facility as if both magnets faced each other without any intervening body. The magnet was lastly placed under Boyle's receiver, from which the air was withdrawn as much as possible by means of the pump. Another magnet outside the receiver was then suspended from the beam, and on being lowered to different distances was attracted by the same forces as in a former experiment when both magnets remained in the open air. I am aware indeed that the great Boyle has alluded, in the case of a similar experiment, to a different result in his *Continuation* 1. *of Physical and Mechanical Experiments*, 31; where he says, that *he loaded a magnet with as much iron as it could draw, and then suspending it from a hook in the receiver exhausted the air; on doing which the magnet for some time continued to sustain the iron, but afterwards let it fall;* a circumstance which would seem to shew that in a vacuum the magnet possesses less force than when in the open air. The fall of the iron however was occasioned, as I suspect, rather by a concussion of the magnet produced by the pumping, and which it is scarcely possible to avoid. Besides *in vacuo* the iron mass is heavier than in air; a circumstance which may itself have contributed something toward producing the fall. Moreover it is easily demonstrated, that, in an exhausted receiver, the magnet operates upon the needle with perfect facility, provided both are enclosed in the same receiver; for after the air is exhausted and the magnet is moved around the needle, the latter follows the motion as faithfully as the most obsequious magnet, and is sensitive to the slightest movement; a circumstance which Boyle himself proved by an experiment differing but little from our own.

Now both from our own experiment and from that of Boyle, it is evident, that in a rarer air the magnet does not sustain a greater weight than it does in a denser. Hence I consider as erroneous the observation of Hartsoeker, in his *l'Eclaircis. sur les Conjectures Physiques*, that the magnet lifts a greater quantity of iron in proportion to the greater lightness of the atmospheric air and the depression of the mercury in the barometer. It would be safer to conclude, that neither the rarity nor the density of the air makes any difference in the attractive forces; that the vacuum of Boyle neither increases nor decreases the forces. I have therefore been surprised at the error committed by Sturmius, otherwise a person of great judgment, who was of opinion that the magnetic phenomena were produced by the elastic air, and that it is by the pressure of the air that one magnet approaches another or iron; an error, however, which has been admirably exposed by the celebrated Wolff.

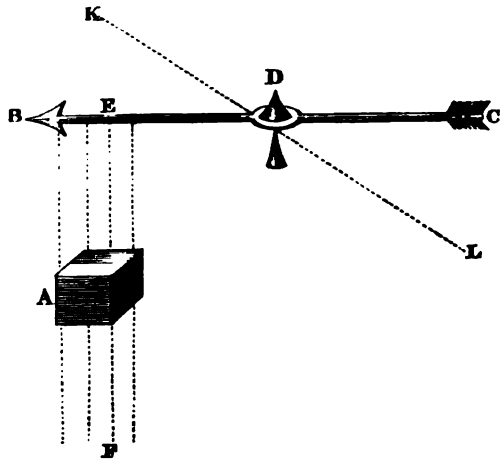
I am not the first person who has noticed the fact of the penetration of the magnetic force through all bodies; but I am not aware that hitherto it has been demonstrated that it remains precisely the same without any decrement. Gilbert, in book ii., chap. xvi., *on the Magnet*, mentions, that its force passes through water, earthenware, and any pyx or other vessel; for says he, "neither thick tables, nor pottery, nor marble vases, nor metals themselves offer any impediment." No body, however solid, takes away or impedes its forces. Whatever substances are interposed, even though they be of the densest nature, as they do not take away its power nor obstruct its course, so neither do they in any manner impede, diminish, or retard it. Kircher, in book i., prop. 2, *Theor.* p. 72, repeats nearly the same words. Schottus, in his account of Kircher, makes the same observation, in his *Magia Magnetica*, chap. iii., § 1, p. 245. Gassendi likewise confirms the remarks, in book x., *Diog. Laert.*, p. 197. The Florentine philosophers ascertained from their own observations, as derived from experiments made with the magnet (*Sperim. fatti in Acad. del Cimento*, p. 247), that the power of the magnet remained the same after having penetrated through mercury; through a wooden capsule filled with sand, or filings of any metal excepting iron; through solid parallelopipeds of stone, or marble; through fifty patinas of gold placed one upon the other; through ardent spirits of wine. Wolffe made the same experiments with a magnet, and noticed the same results: see his *Vernuftige Gedachten*, vol. iii. Leeuwenhoek, in the *Philosophical Transactions*, Nos. 226 and 227, has proved also, that the force of the magnet has travelled through water.

Kircher, after finding that the force of the magnet permeates in this manner through all bodies, gives utterance to the following sentiments in opposition to Epicurus, who maintained that circumfluent atoms, which also urged the magnet, were the causes of all effects; book i., part 2. "How is it that a magnet of this kind can draw the smallest corpuscles of atoms with equal facility and with instantaneous transition through the hardest and most solid bodies into iron? It is probable then that the circumpulsion which was not in the magnet, was only in the brain of Epicurus; and that hence was the occasion of an opinion so dissonant from fact." On the same rock have foundered many of our more recent philosophers; who have recourse to this or other fluids, or to corporeal effluvia of some kind or other, in order to explain the actions of the magnet. But there are other considerable difficulties with which hypotheses of this kind are pressed, beside those we have already adduced; as will further appear in the sequel.

For let us suppose that there are effluvia or fluid particles issuing

from the magnet, and which are corporeal; or, with Tachenius, that there are odours, for he maintains that the magnet attracts iron by an odour. In this case, Fig. 41, let A be a magnet whose effluvia are

Fig. 41.*



carried in the direction E and F. Let BDC be a body extremely mobile upon the pivot D, after the manner of a mariner's needle. Let BDC be made of any metal extremely dense; this metal will consist partly of pores, partly of solid portions. Inasmuch therefore as the effluvia AE run against the solid parts of the metal BC, (for some of them will necessarily do so,) they will also put them in motion; so that the part BD will become elevated to K; and the part C depressed to L; and the elevation toward K will be the greater in proportion as BDC is the less porous. But an effect of this kind is never produced if BDC be a needle made of any other metal than iron; for it remains perfectly immoveable, whether the magnet be placed either above or below BDC. The iron needle alone is moved when the magnet is placed at A. No one who has microscopically examined the solid structure of bodies, will maintain that all metals are so porous that effluvia may pass through them freely; while, on the other hand, that iron is so solid, so little porous, as to receive all the action of the effluvia upon itself; and that this is the only reason for which iron is moved and other metals are at rest. Nor can it be granted that the force of the effluvia AE is too feeble to move the needle BDC made of copper or of other metal;

* In the original, plate IX., fig. 1.

since a similar needle made of iron and placed in the same position, is moved by a magnet with a force equal to a weight of several grains.

Moreover if effluvia proceed from the magnet A in the direction E, and meet the iron needle BDC, will they not repel it farther from the magnet toward K? for as it is in this direction that they are moved, so will it be in the same that they will move the needle. But if the needle, made of pure iron not yet imbued with any magnetic force, be placed upon the magnet A, then it will not be repelled from it so as to cause it to recede, but be attracted by it so as to cause it to approach. This approximation, therefore, requires as its cause, rather the effluvia which enter the magnet and which are carried down by the motion EA; but yet the effluvia which come from without toward any body cannot properly be called the effluvia of that body. We may hence conclude, that those philosophers who have deduced the forces of the magnet from corporeal effluvia, have not sufficiently taken into consideration all the circumstances of the case.

Moreover the supposition that there is a fluid externally surrounding and advancing toward the magnet, and that it is this which is the cause of the forementioned effects, will not be without inextricable difficulties. For let this fluid be supposed to be corporeal and carried in the direction EA toward the magnet, then will it propel the solid body BDC, whatever it may be, placed at a small distance from the magnet, toward the magnet, whether the body be made of copper or of iron; for this fluid will necessarily meet the solid parts of copper in the same manner as those of iron. Yet experiments do not prove this to be the case; inasmuch as the copper needle BDC remains perfectly unmoved, while on the contrary, the iron needle is attracted towards A.

Nor has the explication of Gassendi any place in our estimation; who says, "That the magnetic radii do not attract marble although they attract iron; neither do they attract *festucæ* or other lighter bodies interposed between them; since with the exception of iron and the loadstone, all other bodies possess neither reciprocal radii, nor that disposition of pores or meatuses in virtue of which they refract rays and are themselves acted upon [*stringantur*] by them." But I would ask Gassendi, whether marble, *festucæ*, or other small bodies, do not possess solid parts. I grant that there are pores in them, formed in a manner perfectly different from those which are in iron; still the magnetic radii, which he supposes to be corporeal effluvia, will come into contact with the solid parts of the marble, however few in number those parts may be, and however rectilinear be the direction of the pores, if turned contrariwise to those of the iron. Consequently the radii must communicate some motion, however small, to the marble

and the *festucæ;* yet on experiment no motion is perceived to be communicated either to the *festucæ*, or to the marble, or to other metals; and therefore this opinion falls to the ground.

Besides I would ask, for what reason the fluid moves toward A. Is this the attractive force of the magnet? If so, then will the mutual attraction of bodies toward each other be explained by another attraction equally obscure; which is absurd. Moreover why does the fluid act more strongly in impelling another body, the nearer it is to the magnet; unless it be that its motion is perpetually accelerated? and yet what can be the cause of this accelerated motion, unless we suppose a magnetic attractive force acting with different forces at different distances?

Again, let us imagine a magnet at A, a bar of iron at E, and another at F; and let both the latter approach toward the magnet with a strong force; in this case the iron corpuscles, situated everywhere around A, will approach toward the magnet; an approach which would argue that the fluid also on all sides approaches toward the magnet, where this fluid remains; or does it issue again out of the magnet? The patrons of this opinion may affirm, that it does; as is evidenced by repulsion. But it would be well for them to know, that the repulsion detected in our experiments is much weaker than the attraction; as will appear to every one who compares the experimental results we have furnished. In this case then the fluid will flow to the magnet in greater force and quantity than that with which it will issue out of the magnet. Consequently, in a greater or less time, the pores will become filled, and the magnetic force will cease. Yet we do not find this to be the case; for after an interval of many years we still find magnets to retain the same force.

Let us now suppose the iron at F to be placed immoveably upon a table; and a magnet to be suspended from the beam at A. Let the fluid move in the direction FA, pushing the iron toward the magnet; and let this force between F and A be accurately weighed. Then immediately under the iron at F, let a cube of lead be placed, no matter how thick; will not the cube in some measure impede the afflux of the fluid toward A? If not, we are compelled to suppose the lead to be so porous as to have no solid parts; a position to which none will assent: whether however the lead be interposed or not, the action of the iron upon the magnet remains the same. Consequently we cannot, without the greatest absurdity, suppose the existence of any such kind of fluid.

This hypothesis, however, of an external fluid, or of magnetic effluvia, will come to be further negatived, and without difficulty, in the course of our ensuing experiments.

EXPERIMENT XXVI.

Let a magnet and a plate or rod of iron or steel be exactly weighed, apart from each other; let the plate or rod be rubbed against the magnet. Let the weight of each be again examined, and in both cases the weight will be found to be the same.

The first person who tried this experiment, was Norman; who took two or three oblong fragments of wire, which he had first weighed in a goldsmith's balance; then having rubbed them against a magnet, he again weighed them and found the weight to remain the same. See *Newton on Attraction*, chap. v. Gilbert made the same experiment; book v., chap. iii. Mersenne and Gassendi, ascertaining the weight of some iron before and after its application to a magnet (which they did by using the balance of a bullion-weigher), observed that the weight of the iron remained the same. See *Gassendi*, book x., Diog. Laert. p. 200: also Works, vol. ii., p. 129. Whiston however threw doubt upon the observation in his treatise on *the Dipping Needle*, p. 9; and affirms that the iron becomes lighter after its application to a magnet. For he took a rod four feet long, and which was 4015⅜ grains in weight before it had scented the magnet, but which, after application to it, had decreased in weight by two grains. He next took another magnet, 4584⅛ grains in weight, which, after application to a magnet, had decreased by 2⅛ grains. He then took another, 14792½ grains in weight, which, after application, had decreased in weight 2½ grains. He again took another, 65726 grains in weight, which in like manner had decreased by 14 grains; and he refers to Hawksby as a witness of his experiments. Being desirous of repeating similar experiments with the greatest caution, I took a most accurately adjusted balance; which, although a large one, was set in motion by the $\frac{1}{10}$ part of a grain; and loaded it with a weight of 2 pounds. In order however to prevent the iron, whose weight I was ascertaining, from acting upon the balance, I suspended it at the end of a brass wire 5 feet long; being unwilling to place it in the scale, because the margins of the latter, folded down, contained within them iron wire; this being the way in which the manufacturers at that time made them. I then took some long iron cylinders or rods, of the weight respectively of 2500, 6800, and 14580 grains. These particulars being minutely attended to, I then rubbed some of the pieces of iron against an excellent magnet, and examined each of them separately in the middle of a cellar, to avoid the possibility of any action being exercised upon the iron balance, or upon iron that might be in the floor or ceiling, arising from a communication of the magnetic force. In all these cases, however, I confess that I could not discover any difference

in the weight. In order to be perfectly assured as to whether the balance was sufficiently mobile, I placed the half of a grain successively at each extremity of the beam, which caused it to descend; so that I could not doubt of its mobility. Great of course was my surprise; because these experiments by no means agreed with those of Whiston; which yet were instituted by the most experienced men, to whom I had reason to give credit for much more dexterity and accuracy than to myself. Diffident therefore as to my own results, I proceeded on another day to make other trials with other iron rods and parallelopipedons of 8050, and 15565 grains. In so doing, I paid attention to everything which might possibly interfere with the experiment: putting away all the iron I carried about my person; wiping the axle and the scales of the beam, as also the needle, in order that the whole apparatus might be as mobile as possible. However, on examining the weight, I found it remained unaltered as in the former case. These diversified results therefore of the experiments, depend either upon some difference of force with which different magnets act upon the iron, one of which renders the iron lighter and the other leaves the weight the same; or else upon some difference in the care with which the experiments were conducted. If we examine the experiments of Whiston, they seem to present to view something extraordinary. For iron of 4585$\frac{1}{3}$ grains, lost 2$\frac{5}{8}$ grains; another piece which was heavier and of the weight of 14792$\frac{1}{2}$ grains, lost 2$\frac{1}{2}$ grains. So that the heavier piece of iron experienced a smaller loss of weight than the lighter; while, in another experiment, the heavier piece of iron weighing 65726 grains, lost 14 grains, and therefore more again in proportion. Now these results do not appear to agree with each other; for why should the iron, weighing 14792$\frac{1}{2}$ grains, not lose a greater degree of weight after being rubbed against the magnet, than the iron weighing 4585$\frac{1}{3}$ grains? Still the observations of Whiston cannot be denied; because they are a mere record of experiments. In weighing a body we may, however, easily fall into error, in consequence of not sufficiently attending to the minutest details; as I have learnt from experience. For instance, beginning to repeat the experiment of Whiston, I suspended some iron rods from a long hempen cord of the thickness of a goose-quill. What was the result? I had by chance lit a fire in the room in which I made the experiment; and I remarked that the beam on the side on which the rod was hung gradually became lighter; particularly after I had waited for some little time. Whence I concluded that Whiston was right in his observation, that iron, rubbed against the magnet, becomes lighter. I know not, however, by what chance I was induced to remain still longer, so as to note the difference in the weight more

accurately; a circumstance which led me to observe the beam on the same side to continue to become lighter still. The apparatus I now left to itself, in the same state till the following day; and then I found that the beam on the same side was not lighter as before, but heavier; whence it appeared, that this difference in weight depended on the humidity which had found its way into the cord, which had been expelled by the warmth of the fire; but which, on the day after, when there was no fire, had again insinuated itself into the cord. I therefore in all my subsequent experiments suspended the iron rods by means of brass wire. The scales of the balance had also been always suspended by chains of brass, in consequence of the same inconvenience, which I had observed some time before. But even in this case I never discovered any difference in the weight. In order to omit nothing which might conduce to the completeness of the experiment, I suspended the rods not only in one manner, but weighed them when suspended also inversely. I moreover applied them to the north pole of the magnet, and also rubbed them against the south pole; but always with the same result. I made the experiment on different days, when different winds were blowing; nay, after the interval of a month; but never witnessed a different result. From our experiments, therefore, we are at liberty to conclude, that the weight of the iron, after being rubbed against a magnet, remains the same as before. Let us now grant the existence of a magnetic fluid according to the hypothesis. These effluvia must have their weight; just as all other bodies that we know, possess their gravity. Let the effluvia issue from the magnet and enter into the iron; then the weight of the iron will be necessarily increased, while the volume of iron remains the same. Yet in our experiments, no increase or decrease of weight was observable. On what ground then can we affirm that corporeal effluvia are present in the iron? Perhaps an illustration will be offered from odoriferous bodies, which for a long time give out their effluvia without any sensible loss of weight. In this case, however, a corporeal substance is extracted, which may be retained by metals, taken, and weighed; so that nothing can be proved from the instance of odors. In examining these experiments I bestowed no little labour; because if any difference is found in the weight of iron after being rubbed against a magnet, then it manifestly appears that two conclusions must follow; 1. That the magnet is under the regimen of corporeal effluvia, and that these have communication with the iron. 2. That if the iron be rendered lighter, its effluvia must be deprived of their gravity, and must also take away part of the gravity from bodies; conclusions which involve important consequences to the physical laws of nature, and no little change in philosophy, particularly as expounded by Newton.

EXPERIMENT XXVII.

Fig. 42.*

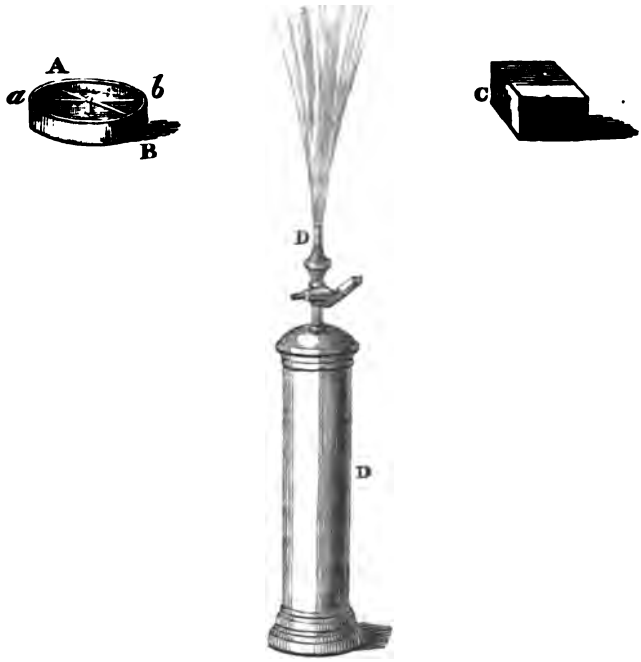


Fig. 42. Let a mariner's needle be placed in its meridian AB, enclosed in a capsule of copper, and covered in on the top with a glass, the borders of which are cemented to the capsule so as to prevent any air from coming in or going out. Let the magnet C be fixed at a certain distance from the needle, so as to direct its point A to *ab*, that is, to some given degree from the meridian which should be borne in mind. Then in the copper vessel D let the air be condensed as much as possible by an air-pump. Let the vessel D be placed in such a manner below the continued right line ABC, that the orifice D may be exactly under it. Then let this orifice be suddenly opened, and observe also whether the needle *ab* be put in motion. The air issuing from the brass vessel will produce a very powerful blast, which will continue for some time, and yet the needle will be seen to remain unmoved. Let us now suppose that there are magnetic effluvia, or some other fluid,

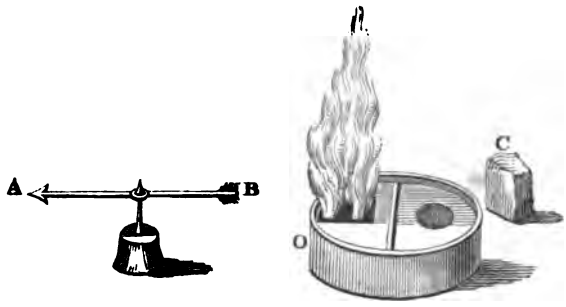
* In the original, plate IX., fig. 2.

directed from the magnet toward the needle, I ask whether the motion of this fluid will not in some measure be affected by the impetuosity of the blast, and consequently whether in the meantime the directive force of the needle will not act from *a* towards A; for before the orifice D was opened, this force was in equilibrium with the attractive force of the magnet. But if the wind thus excited be unable to act upon the fluid, of what nature can this fluid be? Surely not corporeal; for it cannot be that an extremely dense artificial blast, which, by its impetus and velocity may sometimes be made to overcome the natural wind, should not act upon the fluid, nor propel it upward and disturb its motion. Since, however, neither any perturbation nor any motion was observed in the needle *ab*, it follows that by this experiment the hypothesis of magnetic effluvia, or of any other supposed fluid surrounding the magnet, however subtile, cannot be maintained.

EXPERIMENT XXVIII.

Fig. 43. The needle AB being inclosed in a capsule and standing by itself, there was placed in the line of its meridian AB, the magnet C, at a distance of 6 inches; by which it was directed into the position *ab*; then instead of the vessel D, a large saucer full of spirits of wine was used; from this when ignited issued a high and broad flame, filling all the space between the needle and the magnet. This flame continued to burn as long as the spirit afforded proper nutriment, which was administered in large quantities in order that the observation might be protracted to as extended a period as possible, and that we might with the utmost accuracy ascertain whether the needle *ab* always looked the same way or not. Now no aberration from the line *ab* occurred during the time of our observation; and when the flame was put out, the needle remained altogether unmoved. The same result from a similar experiment is recorded by the Florentine philosophers, in *Sperim. fatti in Acad. del Cimento;* also by Wolffe in his *Physics*, vol. iii., and Polinieri in *Exp. Phys.*, p. 295. But since the flame of the burning spirits of wine was exceedingly thin and rare, and not very warm, I thought it desirable to produce a stronger and denser flame, in order to avail myself of a still stronger argument. I therefore lighted the large burning lamp O, the flame of which being fed with oil of rape-seed was extremely hot; and was moreover condensed by the force of an impetuous blast from a large bellows, so that it would melt glass and every kind of metal in a very short time. This flame was so disposed

Fig. 43.*



as to cut the right line, continued from the needle AB to the magnet C, at right angles. The needle AB was deflected from its meridian by the attraction of the magnet C. Between the lamp O and the needle AB was held a plate of glass, in order to prevent the needle from being disturbed by the motion of the wind passing through the flame. As long as the lamp continued burning, the direction of the needle was not changed but remained in a state of perfect rest.

But let us again suppose that there exists a magnetic effluvium, or some other fluid, carried from the magnet C to the needle AB; that the needle is hence deflected from its meridian and is in a state of equilibrium with the directive forces of the effluvia; can it be presumed that these imagined fluids will pass without any decrease of their forces or change of direction through the densest and hottest flame, the parts of which are very solid and move with infinite rapidity?

If however there be any decrease in the forces of the fluid passing through the flame, then will the needle in proportion tend to return to its former meridian; being directed by the forces acting upon it *a parte antica*. But yet we find that it stood motionless as long as the experiment lasted.

Now hitherto no one has found any motive power in the universe stronger than that of fire; since by its tenuity, intensity [*durities*], and celerity, it dissolves all bodies, prostrates them to the ground, or destroys and dissipates them. Shall then the power which sets all other things in motion, be incapable of dispersing the magnetic effluvia? if so, what species of body must they be? If its particles are of diminutive bulk; if they are mobile and solid, like the parts of all other fluids; then may they be struck by other corpuscles impinging upon them; as also retarded, pushed back, or moved in some different

* In the original, plate IX., fig. 6.

direction, like larger bodies. They will therefore be propelled by the fire and the flame, the parts of which cannot but meet the effluvia; whence the direction of the needle AB must necessarily be changed; but if it remains unmoved, it follows that the effluvia do not pass from the magnet through the flame; and consequently that the operations of the magnet are not owing to any fluid or effluvia.

Let any one examine the several arguments which we have alleged against the hypothesis of an aërial or etherial fluid, or of effluvia, which are said to be the cause of the magnetic phenomena: let him compare them with each other, and see what they amount to, and it will be impossible for him not to be convinced, that the magnet is under the influence of some *other* cause, and that the existence of effluvia is only an hypothesis such as was assumed by Empedocles, Democritus, Leusippus, Epicurus, Lucretius, Des Cartes, Sturmius, and other celebrated men; but which as a fact has never been demonstrated. Consequently all the other theories founded upon it are equally groundless.

CHAPTER IX.

ON THE VARIOUS MODES OF DESTROYING THE POWER OF THE MAGNET; AND ON THE CHEMICAL EXPERIMENTS MADE WITH IT.

A PRIORI OR FROM FIRST PRINCIPLES.

By means of ignition or of great heat, the magnet is made to experience a loss of its forces; as also of the rectilinear and regular disposition of its parts; and together with these, of its magnetism; whence it assumes the nature of iron, and is unable to form around itself any regular sphere. After ignition nothing remains which enables it to adjoin itself to another magnet; with the exception of its parts of iron. For the fire itself, as we have above observed, sets in motion every particle of the compages of the harder bodies, and by reason of its own inquietude is perpetually assailing and molesting it; resolving one portion into a fluid; ejecting another in the form of flammules or sparks; and pursuing another from place to place. Hence the rectilinear disposition of the parts it converts into one that is irregular and but little magnetic. Consequently after undergoing such a series of changes and internal commotions, the magnet is no longer enabled to maintain its character. It is no longer a mechanical or regular geometrical structure; no longer endowed with regular passages leading from one pole to another; consequently has no longer a regular sphere formed by a tide of effluvia. After therefore its extinction as a magnet, there remains of its former virtue nothing but the iron; nothing but this which is capable of conjoining it with another magnet, and

which by contact can restore it to its former condition. Thus in Fig. 20 (p. 241), we see a magnet not yet heated; having within it lines running straight from one pole to the other, or from one wall to another; as from *b* to *c*, from *d* to *e*, from *f* to *g*; whence the effluvia at *ceg*H can harmonize themselves into a regular sphere. In Fig. 19 (p. 241), however we see a magnet after it has been heated; in which the parts at *abcdef*, divaricated one from the other, refer themselves not to one but to every possible direction; the consequence of which is, that neither any pole, nor axis, nor sphere can be formed.

2. *From sublimations, solutions, and other chemical operations on the magnet, its parts, and texture, nothing further can be elicited, than that a magnet may consist of parts of a diversified nature; but that the magnetic virtue and quality reside only in the iron particles.* When philosophers, both ancient and modern, could not penetrate into the causes of the magnetic virtue, they endeavoured to eviscerate and examine the magnet anatomically and chemically: imagining that by these means something would be brought to light, in which they might see the magnetic virtue, just as by dissection we are enabled to see the heart and the lungs. Their attempts however were always fruitless; particularly as the magnet admits of no opening or section of its veins, without destroying the rectilinear direction of its parts, and, together with it, the magnetism, or the force, virtue, and soul as it were of the magnet. Some have pounded it into a fine powder or pollen, and have repeatedly distilled and cohobated the dust in some one or other menstruum through a retort or phial. Others have tested it, by passing it through a retort with salts and empyreumatic oils; with acrid spirits, both acid and alkaline; as also with sweet ones. Others have digested the filings of the magnet by submitting them to a gentle heat in sand, in a furnace, or on a dung-heap; they have busied themselves with extracting the tincture by means of some essence or menstruum mixed up with it. Others have macerated it under a cold temperature; have inspissated and precipitated it. Others have tried to fix it by mercury; others, by placing it in a blast furnace, to reduce it to ashes or to calcine it; others have attempted to roast it in furnaces by a slow heat, and to reduce it to rubble [*cementare*]. Others have exposed it

in the focus of a burning glass to the concentrated rays of the sun; others have melted it down into a vitreous substance. Nor do they appear to have omitted any chemical torture, to which this poor unoffending stone has not been submitted; by inflicting upon it thousands of bruises, and submitting it to the ordeal of the crucible in order to force out from it the secret of its latent virtue. But all has been in vain; for nothing further could they elicit than that the magnetic stone consists of entities of the most different kinds taken from the mineral kingdom; as for instance, of stones of various kinds, of sulphurs, salts, and metals; as also that the residuum or only thing upon which the magnet can act, is iron; which, on the approach of the magnet, revives and as it were resuscitates itself. Since therefore all its force and strength consist in the regularity of its pores, and in the geometrical situation of its parts; and since it owes its virtue to its effluvia and mechanism; to what purpose is it to inflict this chemical laceration and flagellation? What can one hope to gain from it? Is not the attempt of the same kind as if one wished by menstrua, salts, or fire, to extract the image of the spectator out of a looking-glass? or the various prismatic colours out of a prism, or out of the skies? or the various rays of light, out of the organ of vision? or mechanism, out of the ashes of a machine? or as if one attempted out of a substance to extract its modes; or out of flint or steel, the sparks of fire; or out of the blood and medulla of Archimedes, to elicit by dissection and analysis his mechanical genius? You cannot from a form extract an essential; all that can be done in the case of the magnet is simply to obtain the iron: which like the ramenta of all iron will approximate and elevate itself toward the magnet. But if we effect a chemical destruction of the iron, then we effect also a destruction of every quality capable of exhibiting magnetic phenomena.

Nor if we plunge the magnet into any acid or corrosive menstruum, shall we by these means deprive it of its virtue; unless the menstruum be so subtile and powerful as to penetrate the entire mass, to dissolve its interior parts, to inflect and invert them into a different position, to destroy the rectilinearity of the passages, and to incurvate them in every direction. A

menstruum of this kind acts similarly to fire; deprives the magnet of its form, and consequently of all its virtue.

3. *By comminution of the magnet into dust, the magnetic quality is lost and confounded.* For if the magnet be converted into powder or grit, then in every particle of the powder or filing there remains some portion of the conjunctive virtue or force, endeavouring to form around itself an extremely small sphere; but inasmuch as one particle has a different position from another; inasmuch as one looks obliquely, another applies its pole to the equator of the other, or to a similar or dissimilar pole; inasmuch as all join their sides to each other at different angles, so that there is no rectilinear transit from one to the other, and hence through all; there is no regular circumambient sphere, nor any power of magnetically alluring the iron to it. Just as we see in the case of ice or glass; for, when reduced to a powder or pollen, their pellucidity and transparency vanish, although in each individual particle there remain regular meatuses for transmitting the rays.

4. *However by the application of some kinds of salts, the interior parts of the iron or of the magnet may possibly become so implicated with them, that the iron or magnetic effluvia may have no power to exhale, and hence to separate itself, until a melting heat disengage the iron parts from their restraint.* For saline corpuscles are capable either of dissolving or uniting the parts of smaller and larger compositions and connexions in hard bodies; as is well known from chemical experiment. For by these means, as by so many hooks and links, the subtile and cohering parts of iron may become implicated and manacled together; thus they may be so coerced as to be no longer capable of disengaging themselves from their bonds, unless by the aid of fire, which shall unfasten, dissolve, and dissipate them. By means of salts not only may metals be destroyed, but reduced into substances foreign as it were and unlike themselves; as for instance, into vitriols, *croci*, *ochræ*, *lunæ*, and other things from which they cannot extricate themselves except by a division of their parts, or by fire. Hence also possibly there are some salts, which, acting as obstruents, block up the pores and deprive all the most subtile parts of the power of emitting and exhaling themselves. Knowing

nothing however as yet of the mechanism of the interior texture of metals, nor of the figures of salts, nor of their operations in menstrua, we are obliged, when referring to them, to reason only in the dark: hence in treating of the subject, we cannot introduce any principles of mechanism, but must refer only to the evidence of chemical and general experiments. Consequently, deriving our information only from this source, we cannot arrive at any certain conclusion beyond the simple fact, that by some kinds of salts the smaller parts of metals may be held fast; and cannot be liberated, except by fire by solution, or some other chemical expedient. Thus also the parts of the iron being under the coercion of binding saline particles, and being deprived of all liberty of unfolding their forces, are unable to form any consociation with the magnet. Of these subjects, however, we shall treat further in our theory of the mineral kingdom.

A POSTERIORI OR FROM EXPERIMENTS.

EXPERIMENT XXIX.

A magnet, which, when held to the needle or over filings of iron, gave indications of very considerable attractive forces, was placed in the fire of a blast furnace fed with charcoal and coke,* so as to make it continue red hot for the space of five hours. After cooling, when applied to the iron filings, it would not attract or lift the slightest particle; all its powers, as was evident from the first, being entirely destroyed; as indeed is confirmed by De Lanis and Boyle, who assert that fire expels from the magnet all power of attracting. Lemmerius also, by another experiment recorded in *l'Hist. de l'Acad. Royal*, A.D. 1706, attempts to prove the same phenomenon; observing that a magnet, exposed to the solar rays in the focus of a burning glass, although not for such a length of time as to cause its fusion into glass, lost all its attractive power. And yet a magnet which came under my inspection, when placed at the distance of half a digit from a mariner's needle 6 inches long and highly mobile, gave manifest indications of surviving forces by its moving the needle, attracting, and repelling it;

* Carbonibus fossilibus ligneisque.

and I am inclined to think that in the magnets examined by those learned men I have just mentioned, there still survived some slight symptoms of magnetic force, which would have discovered itself, had the magnets been applied rather to the needle than to iron filings. For I heated the magnet in so strong a fire, that I doubt whether De Lanis and Boyle exposed their own to so great a heat; except in the particular case in which the focus of a speculum was employed. Let no one, however, imagine that a longer duration in the fire would have produced greater effects upon the magnet, or have prostrated all its forces; for from the chemical analysis of the loadstone it will be evident in the sequel, that the magnetic forces are never entirely destroyed by fire, even though the experiment be frequently repeated. Since however, in a preceding experiment, we have intimated that fire does not act upon the forces of the magnet, while in the present case it is evident that the fire considerably diminishes its force; it cannot but be a matter of surprise that upon one and the same kind of body the operation of fire should be so diverse. I suspect, however, on examining the result of the experiment, that the fire had expelled from the magnet certain particles, such as iron and others, upon which the whole attractive force depended; hence that the residuum was no longer attracted by the magnet. I, however, pounded a magnet into a subtile powder, and at the distance of two or three inches held to it another powerful magnet, which attracted the whole of the dust, lifting and carrying it just the same as if they had been iron filings. The fire therefore had not as yet expelled from the magnet those particles in which the attractive force resided; for then the powder would have remained undisturbed, and not have fled to the magnet; whereas it gave indications of an attractive force still surviving within itself; since where there is no reaction there can be no action; for all bodies necessarily attract each other with equal and reciprocal force.

In this stone the fire had changed the figure of the pores; for the stone had become lighter and redder; but it could not therefore be said to have lost its power; for what is a pore but a part of space which by nature is inert, and which, whether circumscribed by limits in this way or the other, cannot acquire any forces? consequently a merely changed figure of the pores cannot be maintained as a cause of the loss of the forces. For the fire acted upon something that was in the magnet; no doubt therefore that it acted upon something corporeal. It likewise operated in such a way, that, whereas the stone before possessed considerable powers of attraction, the fire had now in some measure expelled or rather silenced them; silenced, we say, rather, because in the magnetic dust the magnetism was again observable when exerted by the

other magnet, which resuscitated in it the same forces with which it had been formerly endowed. A very powerful fire therefore only subdues the magnetic forces; because when a gentle heat only is employed the magnet does not lose them. Artizans often join together various pieces of magnets by a circumfusion of melted lead, tin, or other compound metal; but we find in the present case, that the magnetic forces are not destroyed by the heat, but remain entire and steadfast. These forces therefore obstinately inhere in the magnet, and are not to be expelled except by the strongest power of a long continued fire; and even in this case perhaps are not so much expelled as subdued. Still there is no little obscurity overhanging the subject, as to what that is in the loadstone in which the magnetic forces reside, and what is the manner in which it is agitated or affected by the fire, so as from having been active to be made inert. Here intellectual sagacity has availed nothing hitherto; for indeed were this point arrived at, then would all the magnetic effects and operations be also well understood. If the unknown cause were corporeal, and issued out of the magnet, then when the magnet operates there would be effluvia from the afflux and reflux of which would arise all the phenomena. But we have above intimated by what numerous difficulties the doctrine of effluvia is beset; so that this is a position which we cannot maintain. If again it were a something corporeal which does not issue out of the magnet, how can it agitate, move, and allure to itself, bodies which are placed at several feet distance? This again is a question we cannot answer. Yet is it not an established law of nature;—a law impressed by the Creator upon all bodies, that when they are placed near each other, or at some given distance, they attract each other, and mutually approach and cohere; although there be no extrinsic agent to push them; nothing in the intermediate space to attract them? and if this law be granted, will not one magnet approach toward another or toward iron; and will not all its operations follow from this cause? Yet although I grant that such a law is established by the Omnipotent Being, still it does not follow that in virtue of this law the phenomena which are presented by the magnet can be explained; because after being submitted to the fire, or before it is dug from the mine, if in each case the mass was of the same volume, the attractive forces would also remain the same. Now the fire cannot act against the laws of nature, neither can it change or destroy them; and yet it succeeds in expelling the principal part of the magnetic forces. Besides numerous are the difficulties to which this opinion is liable; for it is a matter of daily observation, that if a magnet be forcibly struck with a hammer, so as to cause a vibration throughout all the parts; if it be reduced to

a powder, covered with rust, exposed for a long time to a damp air, made to lie in its meridian in a position the inverse to its natural one, located near another endowed with stronger forces; it becomes deprived of its virtue, is injured, and enfeebled; as is attested not only by my own observations, but also by Des Cartes in his *Principles of Philosophy*, part 4, § 145, n. 33, 34; by Schott, *De Morbis Magnetum*, p. 286; by Wolffe in his ingenious *Meditations;* by Lemmer in *l'Hist. de l'Acad. Roy.*, A.D. 1706, p. 146; by Boyle in his *Magnetics*, edited by Shaw; and by several other learned men. In all these cases, the substance and magnitude of the stone remained the same; and therefore, in virtue of an innate law of nature, did not exercise any less degree of attraction. Nor would the vicissitudes of the season and of the weather give rise to the slightest difference in the forces; a difference however which has been said to exist by the learned Durham in the *Philosophical Transactions*, n. 303. For that excellent magnet which is in possession of the Royal Society of London, sometimes so suspends iron as to cause it to adhere to itself at a distance of 8, 9, 10 feet; although at other times it does not sustain it at a distance of 3 or 4 feet. Now no one would say that a change of season could induce a change in a law of nature; consequently it is obvious that this change cannot be the cause of the magnetic phenomena. The magnetic force of the loadstone must depend upon some other cause; and the attractive power exhibited by this stone ought to be carefully distinguished from the several other attractive powers which are observable in bodies, and which are equally endowed with other properties, and are subject to a different law.

On a consideration of the difficulties attending the various speculations concerning the causes of the magnetic forces, propounded by different learned men, it might possibly be expected that I should take upon myself to assign some other cause, by a reference to which the various phenomena of the magnet could be resolved and demonstrated, and which I should undertake to prove to be the only true one. Nor indeed has my attention to this subject been slight, comparing as I have the various experiments one with another, inventing various hypotheses, carrying on different experiments in new ways; but the more I laboured, the farther I found myself from the prospect of arriving at the true cause. Hence tired of further investigations and conscious of my incapacity, I am compelled candidly to confess, that the cause of the magnetic phenomena still remains a secret, unknown by any mortal being. Indeed the learned Whiston, who was so skilled in the science of the magnet, acknowledges that he himself had taken considerable pains in attempting to discover the cause of the magnetic forces; yet

that he could not find any hypotheses to satisfy him; none which should be capable of resolving the phenomena into their mechanical principles; and therefore that he was unwilling to obtrude any upon the learned world. The learned Hamberger, in his *Elements of Physics*, chap. ix., is of opinion that the cause of the magnetic phenomena is a certain fluid surrounding the magnet; and yet he is compelled to add the following observation:—"What the nature of this fluid is; what the nature of its motion, what the disposition of the pores, and how from these causes the phenomena result, we can explain only hypothetically; nor even in this case will any hypothesis altogether suffice." Now this in no wise differs from a confession of complete ignorance as to the cause of the magnetic phenomena; an ignorance which he afterwards acknowledges in his Inaugural Programme on the partialities of the magnetic needle; where he says, art. 17, "that the genuine cause of the hostility and amity of the magnetic poles, or of the magnetism of the needle, he believes to be unknown." Besides, much to our present purpose is the remark of Aphrodisæus, who, after having given the greatest attention to the magnet, exclaims, that the nature of its attractive force is known to God only. If now we consult Galen and Avicenna, we shall find in like manner these authors also incapable of comprehending the nature of the magnetic force, and pronouncing it to be divine. If we adduce the testimonies of other learned men who have paid the most careful attention to the magnetic phenomena, we shall find them confessing that the cause of the phenomena is still latent; we shall find Camerarius also in the judicious remarks in his *Dissert. Taur. Epist.*, ingeniously acknowledging, that the reasons for the magnetic phenomena are still undiscovered, and particularly for those which concern the declination of the magnet,—a remark to which Wolfe gives his assent in his ingenious *Meditations*. From the experiments and arguments we have adduced, it is evident, that the cause of the magnetic phenomena is not to be found in any magnetic effluvia, or in any vortices of a fictitiously circumambient ether; for, to use the words of Whiston, "I cannot divine any motion of any subtile fluid pertaining to the magnet, of such a sort as to exercise an attractive force in the reciprocal sesquiduplicate ratio of the distances." And even could we conceive the existence of the motion of such a fluid, this would not suffice to enable us to maintain that a fluid of this kind was the true cause of the magnetic phenomena; as in a parallel instance Cotes has observed in his preface to the work of Newton. Or does it consist in some *Motive* or *Local Blas*,* as Helmont supposes? What

* The term *Blas* was coined by Van Helmont, by which he means, as he says,

however is this but mere words unintelligible to any one? Must there be then some universal soul or spirit which is the motor of the magnet; such as Hermes, Zoroaster, Orpheus, and other more recent philosophers believed? If so, the cause of the magnetic phenomena cannot be mechanical. Before however we admit the existence of this spirit, and its power of attracting or of pressing against bodies, this very existence has to be demonstrated; which no one has ever yet been able to do; unless by this spirit we understand that God who is the most wise author of all things in the universe; who is the first moving power of all things; by whose efficiency are produced the magnetic effects which flow immediately from Him, without any, or without many, intervening causes. But this immediate operation of God upon the magnet we cannot prove; although nothing can be more certain than that in following up the train of causes we must ultimately arrive at God, we must end in Him as the first cause of all things. Between God, however, as a cause, and the magnetic forces, there must intervene some other cause; for the same magnet either acquires or loses its forces according to the different position in which it is placed. It loses, in some measure its forces in the fire. Also iron acquires magnetic forces by hammering: the more it is hammered, the greater are the forces acquired; a circumstance which excites in me a suspicion that there must be some other intervening cause. The various other discordant hypotheses of different philosophers I shall pass over. They may be found in Gilbert, book i., chap. i., and in Cabæus, book ii., chap. ii.

If any one will seriously consider the foregoing remarks he will readily perceive, how remote we are from a knowledge of the nature of bodies; although some persons boast of their possessing it as if it were to be found in some one or other universal attribute. But let these persons try whether from the nature of bodies known, as they think to themselves, they can educe the nature of the magnet and of its forces; and this without obtruding upon us hypotheses as they are accustomed to do, but by offering to us fair demonstrations.

The only way remaining to us, as philosophers, of detecting the cause of the magnetic phenomena, is by rejecting the lust of hypothesis, as I have often said, and which cannot be too often repeated; and by dedicating our labours to the institution of experiments and to observations upon the magnetic phenomena; thus by seriously setting

the force of motion both alterative and local; of this he makes two kinds; the *Blas Meteoron*, and the *Blas Humanum*. The first belongs to the stars and is the pulsive virtue by which they perform their courses; this is their *Local Blas;* the *Blas Humanum* he supposed to operate in men and brutes. (See *James's Medical Dictionary.*)—*Translator.*

to work, and not by wasting our time in sitting still and doing nothing but indulging in reveries; for as Reaumur has wisely observed, "natural philosophy has been studied too much in this manner and to its prejudice." In this case we might possibly, in course of time, perceive some ray of hope; and some gifted person might arise, who, by comparing the numerous magnetic operations one with another, might bring to light their cause; in which case how would posterity wonder, that truths so palpable were unknown to us, although in the present age we bordered so closely upon them!

EXPERIMENT XXX.

Seeing that by the aid of chemical analysis we not unfrequently detect the different parts which compose the larger bodies, I resolved to examine the magnet by this method; suspecting as I did that this body was not simple, but compounded of several others of a different nature; which, if I could succeed in separating, would afford me some prospect of arriving at those inert parts which are endowed with no attractive force, and also with those other parts in which all the force of magnetism resides; so that from these, as examined by the microscope or in some other way, we might discover the fabric of the magnet and the cause of its virtue. I therefore directed my whole attention to a dissolution of the magnet into its more simple parts; supposing as I did that it was a body compounded of other bodies. Boyle had in some measure preceded me in his attempts; but had made such little progress, and was comparatively so little careful in his manipulations, that I could derive from them little or no light. I have thought it desirable however to present them to the reader in conjunction with my own; particularly as they may be dispatched in a very few words. This philosopher heated different magnets in the fire, and then observed a great heterogeneity in their substance; some, as they cooled, dissolved into dust; some became friable; others remained entire; others appeared to have interior cracks, causing a resemblance of scales of iron; others resembled lamellæ of variegated colours and parallel one to the other; others appeared as if they had undergone scarcely any change either in colour or solidity.

None of these magnets, when in the fire, emitted a blue flame indicative of the presence of any sulphur; although Del Porta affirms this to be the fact, supposing that the magnetic force consists in sulphur. From these extremely diverse forms of magnets submitted to the fire, it is evident that the substances concurring to compose them

are various; some of which are more and others less volatile. We now however hasten to the analysis of the magnet, which we shall conduct in different ways; so that what is not discovered by one method may be so by another.

FIRST PROCESS.

Inasmuch as the entire magnet, when roasted for some time in a fire, so far loses its power of attracting iron, that it ceases to attract filings, although it acts upon a magnetic needle six inches long, I endeavoured to ascertain whether it were possible to expel the whole attractive force of the magnet. This it appeared would be the more easily effected, when the magnet should be first reduced into an extremely subtile powder, and then submitted to the fire. I therefore selected a magnet of excellent power and of a blackish color; which I pounded, in a mortar, into an extremely fine powder. I suspected that in this dust there would be some parts which would be attracted by the magnet, and others which would not. I therefore by the aid of an excellent magnet endeavoured to separate one powder from the other; but the whole was so homogeneous that every portion became attracted. I then measured the distance from the magnet at which it exhibited this attraction, in order that I might afterwards know whether the powder produced by artificial processes possessed a greater or a less attraction than this. I now placed the powder into a crucible which was open above; this crucible I placed in a blast furnace, and heated in a strong fire made of charcoal piled up around it. This I continued for the space of three hours, during the whole of which time the crucible was white hot. On examining the crucible when allowed to cool, the same powder appeared and of the same color as before ignition. The powder which was in the crucible, before being submitted to the fire, I had exposed to a needle six inches long, to which I gradually moved it in order the more readily to ascertain at what distance it influenced the needle. This distance I had noted, and now again on exposing the crucible with its powder to the needle, the former attracted the latter at the same distance as before. I next held a magnet over the powder which had been shaken out of the crucible; but the powder was not immediately attracted at the same distance as before; though after waiting a minute or two, I found it attracted as strongly as before the ignition.

I did not attend to the weight of the magnet before and after ignition; because I could not prevent the charcoal from falling into the crucible and so altering the weight.

From the result of this experiment we learn, that the attracting force of the magnet cannot easily be expelled by fire, although it may be considerably diminished throughout the entire mass of the magnet. Whence it would seem, that after the magnetic force has decreased down to a certain point, the ignition of a few hours longer will not cause it further to decrease; a circumstance which shews that the principle of attraction in the magnet is not very volatile.

SECOND PROCESS.

I next tried whether the principle of the magnetic attraction could not be volatilized, by mixing with the magnetic dust saline substances; such, for instance, as in general exercise the greatest subtilty in penetrating bodies, and carrying away and causing to ascend all that can be rendered light and subtile. To this end I took three drachms each of the same magnet reduced to pollen, and of corrosive sublimate of mercury. These two, pounded together and well mixed, I poured into a glass phial, which I exposed for three hours to a hot bath of sand. All the mercury was now sublimated, and adhered to the top of the arch and to the neck of the phial, as in all other cases of its sublimation; yet it had not carried up with it any portion of the magnet, which still remained in the form of dust at the bottom of the phial. When the phial was broken and the dust extracted, the same attractive force was observed to be retained as before undergoing the operation.

2. Inasmuch as in chemistry we sometimes find, that we are unable to effect by a solitary operation what may be effected by repetitions, I collected together the former sublimated mercury, and mixed with it 11 scruples of crude mercury, as also the same dust of the same magnet. These three I put into a glass phial, and again exposed it to the heat of a sand-bath for three hours; after which I found the whole of the mercury sublimated to the top of the arch of the phial; and yet it had not carried up with it any portion of the magnet, which still remained at the bottom of the phial in the form of dust, of the same colour as before, and which, when examined by holding over it another magnet, was found to have lost none of its magnetic virtue.

All the mercury which I could collect from this operation I again carefully mixed up with the same powder of magnet, and put into an earthen crucible, which remained open at the top in order to let me see what effect would be produced by submitting it to a more powerful and an open fire. Because from the different modes of applying heat, it is seldom that we do not obtain different products. I therefore committed

the mass for one hour to the fire of a blast furnace; when I found that the mercury had fled off, leaving in the crucible the same powder of magnet, changed neither in color, in quantity, nor in the attractive force which it manifestly exercised upon the needle and the magnet. So that from these trials it is obvious that mercury does not act upon the magnet, or change, corrupt, volatilize, or separate, any portion of it, but leaves the substance altogether intact.

THIRD PROCESS.

Although the sublimate of mercury did not volatilize any portion of the magnet, I could not therefore conclude that no kind of salt could do so; because salts are of very different natures, and frequently one will act upon certain bodies while others are inert; as will be evident, not from the present, but from some of the ensuing processes. I therefore took a fresh portion of magnetic dust, but belonging to the same magnet which I had employed in the preceding and all the subsequent operations. To this I added of arsenic three drachms; both powders I mixed well for some time; and having enclosed them in a glass phial, exposed them to the heat of a sand-bath. In the space of two hours all the arsenic was sublimated, and a great portion lodged upon the neck of the phial, leaving at the bottom the powder of the magnet unchanged either in quantity, colour, or attractive force as exercised either upon the needle or another magnet. From this process, therefore, we learn nothing, but that arsenic does not act upon the magnet.

FOURTH PROCESS.

Inasmuch as ammoniacal salt volatilizes iron and is sublimated with it, I imagined that it might partly or wholly volatilize the magnet. Nor were my expectations disappointed. For I took three drachms each of ammoniacal salts and powder of magnet. Both these were pounded together, and put, when mixed, into a glass phial, which I placed in a sand-bath for three hours. The fire was not very strong, because the pot containing the sand was not let very far down into the furnace. On the phial being taken out and broken, there was observed at its bottom a cohering mass, soft, readily friable into dust, and having but little

smell. When broken along the middle from the bottom to the top, it exhibited certain strata arranged in the following manner. The lowest stratum was the thinnest of all, and of a darkish hue; the second was [*fulvum*] of a deep yellow; the third was of a pale yellow [*luteo*]; the fourth was greyish [*gryseum*], consisting of a mixture of the dark parts of the magnet and of the white parts of the ammonia; the fifth or uppermost stratum consisted of the whitest pure flowers of ammoniacal salt, which were light and scarcely cohering.

This mass, when presented to a needle 6 inches long, excited it into visible movements, both attractive and repulsive.

From the diversity in the colour of the strata, and from their different gravity, it was evident that the magnet is not a homogeneous and simple body, but a compound of several parts diverse from each other.

These several strata I felt induced to examine apart from each other; but having my attention called away by other circumstances, I deferred the task till the following day; when I found that the mass had become softened by the humidity of the air; so that the strata could not with any degree of nicety be separated from each other. I therefore now mixed up the entire mass together.

2. Upon three drachms of this mass put into a phial, I poured some water from a well, to the height of one digit. This I digested in a little wooden furnace for eight days; by which time was elicited a tincture, pellucid, moderately thick, from a deep to a bright* yellow, like rust of iron dissolved in water. At the bottom of the phial there remained a considerable portion of the magnet undissolved.

3. The tincture I gently poured out in order to prevent any admixture of the powder. This I inspissated, and dried in a vessel of pure porcelain; a process which gave rise to a dust of an orange color, having a salt and stringent taste, as though it possessed a mixture of vitriol of steel. This dust or powder could not be attracted by the magnet, although the foot of the armature was brought into close proximity with it.

4. This orange-coloured dust was put into a crucible, which I placed upon an open furnace. The first effect produced, was its solution into a fluid, which was ebullient like water, perpetually and copiously emitting fumes. After this the dust remained of a blackish hue, or of the same color as the magnet before undergoing the process; and was strongly attracted by another magnet; as strongly indeed as if the powder of the magnet had not been submitted to the action of fire.

* Ex fulvo flavescens.

5. Another portion of the mass described in sect. 1, I took to the amount of three drachms; and having put it into a deep phial, I poured upon it spirits of wine distilled by itself, with which it remained digested for eight days; whence was elicited a tincture thicker, and somewhat greenish; a great portion of the magnetic dust remaining at the bottom undissolved. This tincture had a sharp and slightly saltish taste.

6. From this tincture I took all the spirit of wine: leaving at the bottom of the vessel a large quantity of dust of a dusky yellow colour [*ex flavo fusco*], and having a salt taste, but most acrid and biting; affording no indications of attraction when either the needle or a magnet was held to it.

7. This dust I put into a crucible placed upon an open fire; when it exhibited the same phenomena as the dust described in sect. 4; and declined into the same blackish magnetic powder.

8. There remained therefore in the phials, powder of magnet not dissolved either in water or in spirits of wine. This I put into a crucible; and on gently drying it, the powder assumed a black colour, and was attracted by the magnet. I then put it into the same crucible as before, and exposed it to a very strong fire for the space of one hour; whence resulted a powder from a deep yellow to a bright red colour [*ex fulvo rubicundus*], which was strongly attracted by the magnet, and at a greater distance than the magnetic powder before undergoing any process.

9. As the fire however was not sufficiently powerful, I repeated the experiment by sublimating a fresh quantity of the powder of magnet with an equal quantity of ammoniacal salt, and exposing it in a phial to a very vehement fire. In the course of this operation I volatilized the whole of the ammoniacal salt, which took up with itself to the arch of the phial a yellow powder from the magnet; the same which in a former operation, with the aid of spirits of wine and water, I had collected in the form of a tincture. In the bottom of the phial there remained a mass from a red to a dusky colour [*ex rubro fusci*]; and which in the open air, within the space of a day, was dissolved by deliquescence.

10. After this I again took three drachms of a fresh quantity of pulverized magnet and ammoniacal salt; and having thoroughly mixed both in a crucible, I exposed it to an open fire in a blast furnace for the space of one hour; at which time the whole of the ammoniacal salt had evaporated, carrying with it a considerable portion of the magnetic powder, but leaving at the bottom of the crucible a powder of a rosy

colour; which was indeed attracted by the magnet, but only in a slight degree, and at a short distance from it.

11. Now, on attending to all the circumstances which occur in the foregoing process, it is evident that in the magnet there are certain parts which can be volatilized sooner than others; for those which constituted the yellow colour in sect. 1, 2, 4, 9, ascended in conjunction with the ammoniacal salt; but those which were of a colour approaching more nearly to the black, appeared to be more fixed or heavy, since they remained at the bottom of the phial. But by this operation we do not penetrate into the art of separating the inert parts of the magnet from those which are endowed with the highest virtue; because those which were volatilized equally retained the attractive force as those which remained perfectly fixed; since the volatile parts had only to be separated from the adhering salt in order to exhibit again the same magnetic force which they did before; as may be seen in sect. 4, 7.

12. Still it is surprising that the tincture of the magnet, whether made with water or alcohol, when dried so as to return to powder, sect. 3, 6, manifested no symptom of attraction, although it contained within itself the magnetic substance, which, after experiencing a still further action of the fire, gave a palpable proof of its attractive virtues. The dried tincture however contains within itself a considerable portion of salt; the salt strongly attracts the magnet, and causes the attractive force to terminate in itself so as not to be able to act upon another magnet. Moreover from all our experiments we constantly learn, that nothing but the salt prevents the force of the magnet from being diffused to a considerable distance; and that all salt restrains its power; not only the ammoniacal, but also sea salt, *sal gemmæ*, and nitre; as will be evident in the sequel. Something surprising therefore takes place between salts and the magnet; the former hindering that which neither metals, gems, stones, glass, wood, or earths, succeed in doing.

FIFTH PROCESS.

Not having attained my object in the preceding operation, I turned my attention to an experiment with another salt; apprehending however that I should not derive much aid from this quarter; since experience constantly teaches that no salt better succeeds in laying open bodies than the ammoniacal; but since in physics we are unable to form many conclusions *à priori*, I preferred assuming the character rather of an

ignorant operator than of a subtle reasoner, who is incapable of scarcely anything but hypothetical argument. Hence I proceeded to pound into a fine powder three drachms each of magnet and sea salt, which were carefully mixed together. These I put into a crucible, and submitted to a powerful fire in a blast furnace for the space of three hours. The particles of dust formed themselves into a solid mass strongly adhering to the sides of the crucible, and incapable of being separated from them except by the fracture of the crucible. The mass had turned to a color verging from red to black, like the *caput mortuum* of vitriol; and everywhere distributed throughout its substance had little points extremely bright resembling those of broken iron. This, when reduced to a powder, was strongly attracted by a magnet which was held over it. Consequently sea salt does not eliminate from the magnet any parts in which its force resides; nor does it eject from it the parts which are inert.

2. Not content however with this single operation, I took the former powder which had already once undergone the action of the fire, and after mixing it with an equal quantity of sea-salt, exposed it, in an open crucible, to a very powerful fire in a reverberating furnace, for the space of two hours and a half; an operation the result of which was a firm mass, closely adhering to the crucible, spongy, with its upper part of an ashy colour, and the lower reddish [*rufescentem*]. The two parts thus differently colored I carefully separated from each other; hoping that by this method I might separate the inert from the attractive portion of the magnet. Each mass, when reduced to powder, was attracted by the magnet; the ash-coloured very strongly, the red-coloured very feebly.

3. From the issue of this experiment I concluded, that the magnet is a body compounded of a dark inert earth, and of some other matter in which the magnetic power principally resides; but that this matter adheres most tenaciously to its earth, and consequently in the present operation was not perfectly separated; for that if it were, no magnetic force would be discoverable in the earth, while the attraction in the ash-coloured powder would be considerable.

4. I therefore endeavoured by a further process to separate this ash-coloured powder from its earth still more completely; for which purpose I mixed up with it an equal quantity of sea salt; and submitted it in a crucible for three hours to a most powerful fire [*igne vehementissimo rotæ*] made of coal and charcoal. On cooling, the powder was observed to be of the same colour as before; and was attracted by the magnet in like manner; nor did I by this method obtain any further separation of the earthy from the other parts; therefore either the part possessing the greatest magnetic force had fled off, or else in the

present operation the fire effected no change. I consequently considered it useless to pursue this method any further; the powder being unchanged by the action of the strongest fire.

5. I therefore proceeded to try, whether I could so far lay open the composition of the magnet as to elicit from it a tincture; to this end I poured a quantity of water upon the dust which I digested for two days; at the end of which the salt alone was dissolved in the water, but no tincture was discernible. On perceiving this, I poured on the powder a quantity of fresh water, then a quantity of salt water, in which I soaked it; and then again a quantity of fresh water, till the latter became perfectly tasteless; after which the powder, on being dried, exhibited the same colour as it did before any experiment had been made with it, and was again also as strongly attracted by the magnet as at first. When the magnet was first held over it, its virtue for awhile was not manifested; but after a minute or two an attraction took place. The powder, once attracted and afterwards wiped, became much more easily attracted the second time, and was visibly moved and elevated; nay, even fled to the magnet from a much greater distance. The only difference occasioned by the violent action of the fire was this; that at first the powder was not attracted so immediately as that which had not been submitted to the fire.

SIXTH PROCESS.

Having already tested the magnet with neutral salt, such as the ammoniacal; and with muriatic salt, such as the marine; I next designed to expose it to the action of fixed alkaline salt. I consequently took three drachms each of magnetic powder and salt of tartar; and both these powders which had been well pounded and mixed together, I put into a crucible which was placed, open at the top, upon the charcoal fire of a blast furnace; where it remained for the space of three hours. After cooling I found a powder of the same colour as before it was submitted to the fire, appearing in no respect changed; setting in motion a mariner's needle 6 inches long, at the same distance as before; and manifestly attracted by the presentation of another magnet.

2. Inasmuch as salt of tartar does not incline to a dry state, but is strongly attractive of atmospheric damp, I now tried to make it deliquescent; and in this state to see what effect it would have in laying open the composition of the magnet; but now, contrary to its nature, the salt remained dry;—a circumstance which seems to result from the great force with which it was endowed in its attraction of the magnet.

3. I consequently put the dust into a phial, and poured upon it water to the height of one digit; in order to see whether, after a process of digestion for 16 days, there would result any tincture. Notwithstanding this, the water remained pellucid and white, holding in solution nothing but the alkaline salt which had adhered to the powder. On observing this, I sweetened the powder by thoroughly washing it in pure water; and then dried it. In this state it gave manifest indications of the power of attracting iron; a power scarcely inferior to the one which I had observed in the dust before instituting any experiment. The powder was nevertheless not pure magnetic powder; because it retained the ashes, mixed up with itself, which had been left from the salt of tartar; and when separated from this by the aid of another magnet, which acted upon the magnetic dust not upon the cineritious portion, I obtained a magnetic powder which had experienced no alteration. This process I pursued no farther; because I had learned nothing from it, except that the most acrid alkaline salt does not act upon the magnet; and as I entertained no hope of making any further discovery by this method, I betook myself to experiments made with another salt.

SEVENTH PROCESS.

I next took three drachms each of powder of magnet and of nitre, which, after being well mixed and put into a crucible, I exposed to the fire of a blast furnace for the space of three hours; at which time they had become a firm mass, spongy, not shining, inclining to black, so strongly adhering to the crucible as to be inseparable without breaking it. This, when again reduced to powder, was attracted by the magnet, and had retained somewhat of a salt taste derived from the alkali into which the nitre had been turned in the fire; and since in this our first operation the mass was of an homogeneous color, and presented no separate and distinct divisions, I for this reason submitted it to another operation.

2. With the former powder I mixed an equal quantity of nitre, and for 2½ hours exposed it in a crucible to a most powerful charcoal fire in a reverberating furnace. The powder turned into a very friable mass, which was again reducible to a pulverized form solely by the fingers; it was also reddish, but everywhere homogeneous, giving no indication of distinct divisions. On reducing the mass into a powder, I found it was but little attracted by the magnet; whence I should have concluded that the part endowed with the magnetic forces had escaped with the nitre, had I not been perfectly sure that this result proceeded from the quan-

tity of salt everywhere adhering to the powder, and preventing the magnetic force within from acting upon other bodies.

3. Having next placed the powder in a phial and digested it with water, I simmered it [*coxi*] for the space of eight days, with a view to ascertain whether it would afford a tincture; which I found it would not. I then soaked and washed the powder in a large quantity of water, until it became insipid: this, when dried, remained of a reddish color, and was attracted by the magnet much more strongly than in sect. 2. Indeed I was in doubt whether there was any difference between the present degree of attraction and that which had been manifested by the powder previous to submitting it to any operation.

From the operation of this salt I was not in hope of making any further discovery. I could perceive indeed that its corrosive quality was different from that of salt of tartar or sea-salt, because the powder became imbued with another colour; for now it was reddish, whereas before it was greyish, reddish, and blackish. Not attaining my object, I prepared for a different method of examination.

EIGHTH PROCESS.

I now took three drachms each of pulverized magnet and *sal gemmæ*, both of which were well pounded and mixed together. I then put the whole into a crucible, which was exposed to the fire of a blast furnace for the space of three hours. This, after cooling, presented a firm mass strongly adhering to the crucible, everywhere interspersed with glittering points, visible through a microscope, but which were only the most pellucid parts of the *sal gemmæ*. On the surface of the mass there appeared an iron colour, which led me to suspect that in the mass there was a considerable portion of iron. In its lower part the mass presented a rough aspect and was much blacker. Not being able to separate the upper part from the lower as well as I wished, I was in hopes the more easily to accomplish my purpose by submitting the mass to another operation. I therefore first reduced it to a powder, which retained a salt and acrid taste, and was strongly attracted by the magnet.

2. To this powder I again added an equal quantity of *sal gemmæ*, and having put it into a crucible submitted it as before to a strong fire in a blast furnace for two hours and a half. The mass on cooling was firm. Its upper stratum resembled the colour of iron; its lower part was spongy, red, and softer. Both these strata, when separated from each other, I reduced to a powder. The powder of the upper stratum was attracted by the magnet much more strongly than that of the

lower. Nay further; in the lower stratum there were various parts which were not attracted by the magnet; while on the contrary all were attracted in the upper stratum.

3. There was much therefore in the lower stratum similar to that which was found in the upper. Hence all that was attracted by the magnet I extracted from the lower stratum, and added to the powder of the upper. With this I again mixed an equal quantity of *sal gemmæ*, which I put into a crucible, and submitted to a strong fire [*igni fortissimo rotæ*] made of coal and charcoal, which was continued for four hours. After cooling, the mass exhibited itself as a dark substance not very cohesive, but very friable, and also homogeneous. To the sides of the crucible adhered pellicles of a certain metal the nature of which was unknown to me, of a silvery colour, shining, and in no degree attracted by the magnet. In the course of this operation the mass had become considerably diminished, so that a large portion of the salt and of the magnet had escaped; the whole of the salt however had not disappeared, because there was manifestly in the mass a salt taste. In all the parts, when minutely pounded, but a small portion of the magnetic force was observed; as indeed I anticipated would be the case; because the salt had penetrated everywhere into the magnetic parts, with which it strongly cohered; inasmuch as the force of an extremely powerful fire continued for so long a time could not separate them. What however fire could not do, water easily effected.

4. I therefore poured water on the powder in the phial, to the height of about one digit; in which it remained digested for eight days: this I did with the view of seeing whether it would afford a tincture; it however afforded none; the only result was that the residuum of the *sal gemmæ* was dissolved in water. On finding this, I washed the powder in a large quantity of water until it became insipid. When the powder was dried, it was of a darker colour than the magnetic powder before undergoing any operation; and was attracted by the magnet more strongly than before; which proved that the admixture of salt had impeded its magnetic action, and that some of the inert earth had been separated from the substance of the magnet; which unquestionably was the same with that which in sec. 3 I had set aside. I however did not doubt but that in this residuary mass was still contained much inert matter; which by means of further and long continued operations might be separated from the active; but I had not leisure to pursue the trial. I hastened rather to other methods, hoping that by these I should more easily accomplish my wishes. From all these attempts however it is evident, that the entire magnetic force cannot be so easily expelled from the magnet as philosophers have

thought, in consequence of seeing a large and perfect magnet receive injury in the fire and lose its forces. The stone however does not lose all its forces; for treat it as we may, it retains some portion of its virtue; as is evident from the experiments we have hitherto made, and as will be further evident in the sequel.

NINTH PROCESS.

I had a strong desire to ascertain whether the magnet, when vitrified, retained its power of attraction; since vitrification is the ultimate limit of chemical operations, and the most effectual means of superinducing change upon bodies. Hitherto I had not vitrified the magnet either by itself or by the aid of borax alone; although I had exposed it to a most powerful fire for a long time. I therefore added the minium of lead, which, with most earthy bodies and particularly the silicious, changes into a beautiful clear yellow glass; rivalling in beauty the prussic amber. The first thing to be ascertained was the quantity of minium with which the magnet would vitrify. It was requisite to begin with the smallest quantity, in order to be the better assured what was the degree of magnetic force which had survived or had been destroyed. I therefore took three drachms each of minium, magnet, and borax, thoroughly mixed together; which I put into a crucible, and exposed to a most powerful fire for the space of three hours. The result was a mass scarcely cohering; which seemed as if it would have passed into a solid substance if only more of the fluxive had been mixed up with it. This was still attracted by the magnet as before; nay, the entire substance was attracted; the minium, the salt, and the magnet, all equally. It was evident therefore that more minium must be added; and inasmuch as in the making of glass there is required three times the quantity of minium as of sand, I added also to the mass three times the quantity of minium as of the magnet; a drachm of borax likewise was put in. This mass I submitted to a most vehement fire in the crucible for three hours; when it turned into an opake glass of a dark colour, very heavy, capable of being poured out, and of being drawn out into strings [*duci*], as is the case with glass; moreover it was everywhere homogeneous. Thus was the magnet changed into glass, having experienced the greatest change it was possible for it to undergo, (if we except that superinduced by the focus of the burning glass,) a change under which if the magnet retains its force, then it will retain it always.

This glass therefore, when presented to the needle, manifestly at-

tracted it equally as much as before the mass had undergone the operation in the fire. It was attracted by the magnet also just in the same manner as if itself had been a veritable magnet; hence the glass when pounded into dust was also attracted by the magnet so as to adhere to its poles like a beard. The lead which was reduced to powder and everywhere surrounded the parts of the magnet, did not impede its forces so much as the small quantity of salt in the preceding processes; a circumstance which is better understood from experiment than from reason, as is the case with many other things in natural philosophy.

TENTH PROCESS.

Since antimony is capable of volatilizing nearly all metals in the fire, by penetrating into their most interior recesses, dissolving them into the most subtile parts, and carrying them off with itself, I tried the effect of it on the magnet, with a view to make it volatilize as much of it as it could, and to leave the rest as an inert and earthy mass. I therefore took three drachms each of magnet and antimony reduced to powder, which were both carefully mixed together and put into a crucible; these were placed upon an open fire of coal in a blast furnace, for the space of three hours. At the end of this time, the mass, after cooling, was found to be much diminished in weight and quantity; but was compact, very friable, and blackish; it also moved the needle; and when pounded into dust was attracted by the magnet, just the same as if it had never undergone any action of the fire.

2. In this mass had remained a portion of antimony, which I was desirous of expelling by a still further process. To this end I took four drachms of the former mass; of common sulphur one drachm; of borax of Venice two drachms (this salt was used instead of nitre, by mistake); and having pounded and mixed all up together and put it into a crucible, I submitted it to the strongest fire in a reverberating furnace, for the space of two hours. This time the mass was slightly liquefied, united to itself, as hard as iron, and of a spongy texture. When held to a needle 6 inches long, at one time it attracted, at another repelled it. In this operation therefore the attractive force was not expelled from the magnet.

3. To this mass, which was again reduced to powder, I added two drachms of nitre, with which I again submitted it to a most powerful fire for the space of three hours. Out of this was educed a black, hard, fragile, and cohesive mass, extremely spongy, porous, and heterogeneous. When presented to the needle, it manifestly attracted it; and even when reduced to powder, every part became strongly attracted

by the magnet; although perhaps a little less so than before it had undergone any operation. Antimony therefore does not carry off with itself that part of the magnet in which the attractive force resides; although it volatilizes a certain small portion.

ELEVENTH PROCESS.

I now thought it desirable to test the magnet with acid salts, which I had not hitherto employed; I therefore put into a glass phial with a long neck three drachms of magnet pounded to powder, and poured upon it spirit of sea-salt to the height of two digits. This occasioned a great effervescence, from which arose fetid fumes; large bubbles also were excited in the phial, just in the same manner as if the spirit had been poured upon iron filings. After a time the agitation subsided, and the matter being then digested for eight days, afforded a tincture intensely yellow; in which was contained the whole substance of the magnet in a state of solution, and almost without any sediment. This tincture manifested no influence upon the needle.

The celebrated Boyle had commenced this process, but had not arrived at any considerable result. He states however that he poured a few drops of this tincture on an infusion of gall, which turned the whole into a black ink; but which, when placed in various aspects, had a blue appearance like the diluted tincture of steel.

On this tincture of magnet Boyle poured also salt of tartar, from which resulted a precipitate which became similar to the solution of vitriol. On another quantity of this tincture of magnet, he poured spirit of fermented urine; by the aid of which he acquired from a yellow precipitate one of a red colour [*ex flavo rubrum*]. But this great philosopher did not examine the forces which these precipitates contained, and therefore I resolved to conduct the same experiments with much greater attention to the details.

2. From the tincture poured into a retort, I obtained, by the aid of a slow fire, all the spirit of the sea-salt; until there remained a matter perfectly dry; in the course of which operation, I observed that the magnet was half volatilized in the solution of the spirit of salt; for the dry matter did not lodge at the bottom of the retort, but had ascended to the neck. It was likewise of a twofold colour; the lower part being purple [*purpureo*]; the upper, pale yellow; but the latter appeared to have been the first deposited by the spirit of salt.

3. Having broken the retort, I made a separate collection of each substance. Neither of them was in anywise attracted by the magnet,

nor moved the needle; and each of them in the open air was incapable of retaining its previous dryness. Here again then was a case in which the magnetic force was reduced to inaction. At first I expected that it would be entirely destroyed, and would not return again to the particles: the case however was the reverse, as will be evident in the sequel.

4. Each mass I again mixed together, and having put it into a phial, poured upon it water, with which I digested it for two days. Hence there arose a tincture intensely yellow, of an acid, astringent taste. A blackish powder had also subsided to the bottom. I poured out the tincture, and added to the residuum pure water, with which I again digested it; whence there resulted a tincture similar to the former, which I again poured out. Then adding water to the residuum, I elicited a fresh tincture, and repeated the operation as long as any tincture could be obtained.

5. All these tinctures, when mixed together and allowed to stay in a vessel for three days, acquired upon their surface a pellicle of a crystallized appearance, and consisting of fibres perfectly straight, small, and exactly parallel to each other. Meanwhile the yellowish dust had subsided to the bottom of the vessel; this I collected, after having slowly and cautiously drawn off the water. This powder, when dried, was of a yellow color, of a salt taste, acid, and extremely astringent, but was in nowise attracted by the magnet.

6. Another powder, which was of a black colour, and which, when gently dried, had subsided to the bottom after digestion and ablution in water, as in sec. 4, was in no degree attracted by the armed magnet. This I therefore put into a crucible, and submitted for two hours to the strongest fire in a reverberating furnace. On cooling, it had a black colour, but contained some small and extremely hard *frusta*, which had coalesced in the fire as if they contained metal. The whole of this powder was again attracted by the magnet. Its attractive force, however, at the beginning, appeared less than that of the magnetic powder before experiencing the action of the fire.

Here then we have the magnet perfectly soluble in a menstruum, on which therefore it strongly operates with its attractive force; since every solution of bodies in a menstruum depends on a force of the same kind, and reciprocal between the two. Hence it is not surprizing that the magnetic force appears not to act upon other bodies, so long as a menstruum is present which so strongly operates upon the parts of the magnet. When, however, the menstruum is removed, the forces return to view; particularly on the approximation of another magnet.

TWELFTH PROCESS.

I took spirit of nitre, made according to Glauber, to the amount of three drachms. To this I added three drachms of magnet pounded to powder, both of which I put into a deep phial; but scarcely any effervescence was occasioned. This I digested for the space of 16 days; whence was elicited a tincture perfectly pellucid, but thick, and verging from a greenish to a yellowish colour;* the dust remaining at the bottom of the phial undissolved.

2. This tincture I gently poured out, and dried the residuary undissolved powder. This being then placed opposite to the pole of a most excellent magnet, exhibited in various places symptoms of a tendency to attraction. Still it was not attracted, unless when placed in immediate contact; so that in this residuary powder the magnetic force was almost entirely silent, a circumstance into which I examined in the following operation.

3. The powder I now put into a crucible, and submitted to the fire of a blast furnace for the space of one hour: when the powder became red and of a brighter colour than red chalk. When presented to a needle 6 inches long, it did not either attract or move it, nor was it in any measure attracted by the pole of a very strong magnet, nor in the slightest degree affected.

This was therefore the inert earth of the magnet, in which no magnetic virtue was to be found; consequently the spirit of nitre did not dissolve but only elicited it from those portions of the magnet which possess attractive virtue.

4. I therefore dried the tincture, which afforded a large quantity of a red substance like the *caput mortuum* of vitriol. This when reduced to powder was not attracted by the magnet; a circumstance which at first occasioned my surprise, and led me to think that in this operation the magnetic virtue had been entirely destroyed. But I suspended my judgment, after discovering from the taste that the powder abounded in an acid salt left by the evaporation, which might possibly be the cause of my being misled, and which happened at first in the case of other salts. I therefore exposed the powder in a crucible to a very strong fire in a reverberating furnace for two hours; the result of which was a powder but little diminished in quantity, of a deep yellow colour, insipid, and which was most powerfully attracted by a magnet; indeed almost as much as the filings of iron, which are attracted by the mag-

* Coloris ex viridiusculo flavescentis.

net more strongly than the powder of a pounded magnet. Truly therefore might I say, that by this expedient I had separated some inert portion of the magnet from that which possessed virtue. This portion however appeared to me to be merely earth, which possibly I might succeed in changing by trying other expedients, but possibly not. I indeed sublimated it with ammoniacal salt, and nearly the whole of the salt became volatilized; but the earth remained fixed, and of a colour much darker than before; indeed no portion of the earth became volatilized by the salt. I afterwards washed and sweetened the magnetic matter with water, in order that, if from the former operations any portion of the salt had been left remaining, it might all be removed. The powder when dried had a dark colour, which in the beginning was slightly attracted by the magnet, but which after it had once as it were scented the magnet, which was gently drawn over it, was of all the powders hitherto obtained the most strongly attracted; and was lifted by the magnet even at a considerable distance. If now we further examine into this subject, we may perhaps find our labour requited. For the method of analysis is never unproductive to those who pursue it; but always originates unexpected discoveries, amply repays the fortune and the fame of the student, and by its surprising results banishes from the mind all the sense of weariness which would otherwise arise from toilsome investigation.

From these various operations it may suffice to learn, that the magnet, treated in whatever manner it may be, still remains a magnet; and that neither by fire, nor by dissolving menstrua, nor by salts, can it ever be so far destroyed as irrecoverably to lose its force; since in spite of all the processes we have here described, it always retained its power, although the salts succeeded in impeding its action. Besides the foregoing, I made other experiments upon the magnet; which however afforded me little satisfaction. I so dissolved it in oil of vitriol, after digestion for 16 days, that the oil degenerated into a small hard stone; which, when dissolved in water, precipitated a powder of a grey colour, of a salt taste, but strongly attracted by the magnet; and which when placed in a fire [*igne rotæ*] for two hours, changed into a red dust, possessing a magnetic force equally as before.

The celebrated Boyle dissolved the magnet in *aqua regia*, and obtained a solution such as is presented by pure gold. This substance might yet be made to undergo various other treatments, and doubtless would display many beautiful results which would commend themselves to our notice by their utility. This however we must leave to time. For ourselves it suffices, that we have begun at least some attempts,

and that we have made some degree of progress, however small, in this department of physics.

Let us now return from this digression, and hasten to other results displayed by the magnet in its effects upon iron; which, although we are ignorant of their causes, will nevertheless much contribute to a clearer knowledge of the loadstone. Some of these results we shall explain by comparing them with others; some we shall only record, inasmuch as we cannot explain or understand their cause, before we have discovered the cause of the magnetic forces. For a long time I doubted whether I should subjoin the ensuing experiments to the preceding; because they are mostly made by other experimentalists, and do not manifest that degree of sagacity which the subject requires; besides which, when put together, they do not form any well arranged series. Inasmuch however as it is from the properties of things that we educe their natures; so also it is by experiments upon the magnet, that we investigate the cause of the attractive force. A multitudinous collection of data therefore is by no means to be rejected; for in these lie all our hopes of solving the problem before us; and the more abstruse it is, the greater number of known data does it require to enable us as well to solve as to understand the problem. We have therefore extended our experiments over a very wide field; and although the utility of them may now be inconsiderable, yet posterity may perhaps derive from them far greater profit than ourselves; and be enabled to introduce among them a more scientific arrangement; since now only as Lucretius observes, lib. 6:

> Hoc genus in rebus firmandum est, multo priusquam
> Ipsius rei rationem reddere possis;
> Et nimium longis ambagibus est adeundum.

It is however to be lamented, that various things are recorded by authors who have treated of the magnet, which are of doubtful authority; at least which are incapable of confirmation in these times, in this part of the world, and with our magnets: inasmuch as philosophers have not conducted their observations with sufficient care, or have inserted into their writings what they have learnt only by hearsay, and have little understood;—a circumstance of which Cabæus complained in the preface to his work on the philosophy of the magnet. "I am well aware," says he, "that there are many writers, and those by no means of the lowest repute, who have transcribed from others certain plausible statements concerning the magnet, which, if submitted to the test of experiment, will be found to be in reality untrue." We

ought not however on this account to accuse any one of error who records an observation differing from our own, for from frequent experience I have learnt how much the phenomena of the magnet differ from each other at different seasons of the year, or even on the same day, if the observations are made with different magnets. Still however philosophers have extruded from out of their brain many of their own fictions, in order to defend an hypothesis once laid down, or to confirm it, as it were, by better arguments; or they have seen in experiments only those particulars which favoured their hypotheses, omitting the others which were concomitant; for most persons are so led astray by self-love, that they see only what they wish to see, and what agrees with their prejudices; while to other things they are blind.

In order therefore to separate from the truth all fable and figment, it was requisite to go over the same ground again, and to reëxamine the experiments recorded by different authors;—a method which sometimes enabled me to detect a not unfrequent cause of error, a universal conclusion drawn from a particular observation. Moreover in the course of my inquiries, I frequently hit upon new modes of investigation, and followed out the attempts which others had only began. The result of these inquiries will be perceived in the sequel.

CHAPTER X.

ON THE FRICTION OF THE MAGNET AGAINST IRON, AND ON THE FORCE COMMUNICATED FROM THE FORMER TO THE LATTER.

A PRIORI OR FROM FIRST PRINCIPLES.

The magnetic parts which are in iron, are, by means of friction, disposed into a regular situation; and a magnetic sphere is thus formed around the iron. If the magnet be rubbed against the iron, which is effected by a contactive trajection or translation of the magnet, then not only does experience, but also reasoning *à priori* dictate, that magnetism is communicated to the iron. By friction the iron is put into contact with the magnet, and all the vorticles adhering to the iron are consociated with the innermost, most acute, and most strongly colligating spires of the magnet. The number of these vorticles, and consequently their ligation, is greatest at the wall of the magnet; for if the ligation, and spiral or trochlear power be strongest at the place of contact with the magnet, then are all the vorticles of the same kind tied one to another the most strongly close to the iron; from hence they inflect their course inwardly into the iron, where they are ready to obey the force of the strongest, that is to say, to follow the direction of the friction of the magnet; whence they dispose themselves into a most orderly array. Thus Fig. 21 (p. 242), if the magnet be drawn from *a* to *b*, then, by reason of the extremely close conjunction of the spires, the interior vorticles follow, in an orderly and continuous sequence, the course of the magnet; so

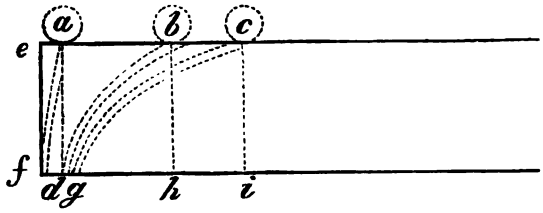
as to incurvate and invert their own path towards that of the magnet from *n* to *o* and *p*, as in like manner also *qrsb* and *td*; whence arises an orderly position, aspect, and exhalation of all the vorticles at the confines; whence also a sphere with a regular axis is capable of being formed, and the iron itself can be made magnetical. For when the magnet is drawn over the iron, it draws and conjoins to itself the smallest parts; particularly those which are wholly or partly loose, just the same as it would the filings or grit [*scobem*] of iron, which adhere to and follow the magnet in a long line, presenting the form and aspect of a beard, or of *styriæ*; so that if a magnetic terrella were rolled over pollen of steel, all the dust would immediately follow in the line of the volution; the one accompanying the other; whence the particles would form themselves into an orderly sequence, and would follow the motion of the terrella. Consequently could we suppose a mass consisting of particles of iron or iron filings, but so constituted that the particles lay loosely and rarely, and that one but just touched the other; then if a magnet were brought near, each separate particle would turn itself in that direction, and obey the slightest movement. Were the magnet drawn along over the length of the mass, the filings would arrange themselves in a corresponding order, and dispose themselves into a corresponding regular sequence. In like manner also when the magnet is drawn over iron, all the smallest particles, or those which are capable of being moved, receive an orderly direction, and thus the magnet creates throughout [*trans*] the iron a certain regular configurated position of the parts. If again the magnet be moved along a plane surface of iron from C to D (Fig. 22, p. 242), then, according to the same mechanical rules, the effluvia, pollen, or dust of the parts, on whatever side the magnet be drawn, will, in this case, arrange themselves within the iron into an orderly position; so that the spires, motions, and oculi of all the effluvia will look from A*g*B and E*if* toward C*h*D; and that they dispose themselves thus into a parabolical site, is a matter of demonstration.

But iron may be rendered the most highly and the most permanently magnetical, if it be rubbed against the magnet, and thus be in actual contact with it; but less magnetical, if it be not in contact. If it be placed at a distance from the magnet, it is

indeed rendered magnetical, so long as it is within the magnetic sphere; but if the sphere be removed, the mechanical order immediately ceases. The more acute are the spires with which the vorticles coalesce, that is to say, the more closely the magnet is moved to the iron, the stronger is its power of reducing the neighbouring parts into a similar situation; for it penetrates into the smaller and more subtile pores. But the farther the magnet is from the iron, or the more obtuse are the spires with which it is applied, the duller is its power, because the less is their ligation; for they penetrate into the wider [*laxiores*] meatuses and pores, but not into the finest; whence also the magnet does not act upon the order of the more intimate parts. Consequently, at a distance, it acts only obtusely upon the iron and its parts; because it penetrates only into the ruder nexuses and pores; by which means the iron is indeed attracted at a distance from the magnet, but there is no acquiescence of its parts, no effective force exerted in bringing them into a regular position.

2. *Iron is rendered the most highly and the most permanently magnetical, when all its parts or its entire compages, are reduced into the same regular disposition; and less or least magnetical, when the parts of the iron are reduced to this arrangement only in certain points, or throughout a shorter distance.* For if the magnet touched the iron only in one or in a few given points, the series of effluvia or of vorticles in the iron, would inflect itself toward the contactions of the iron with the magnet, both to the right and left; hence there would exist no regular disposition or nexus of the effluvia within the iron with those which flow without; consequently no axis extending to each extremity would be formed together with a colligating sphere. Thus Fig. 44, if

Fig. 44.*



the magnet touched only the point *b*, the effluvia from *dg* per-

* In the original, plate X., fig. 6.

haps might direct their course thither, as also from *h* and *i*; and consequently there would exist no rectilinear or other series; hence also no regular disposition of the effluvia at the confines *b*, *c*, and *a*.

3. *When the smallest parts in the iron are once reduced by friction into a regular disposition, they cannot by any numerous reiterated frictions be brought into a still more regular order; nor can the magnetism of the iron be rendered stronger by any multiplication of frictions.* For a figure, once formed exactly and geometrically, cannot by any operation be rendered still more so. The disposition of the parts, when once acquired, still remains the same, though the operation were repeated a thousand times; nor is any other arrangement acquired. Thus, if from a centre we describe a circle, and continue from the same centre to do so a hundred times, we shall describe only the same circle: if by one cause we produce the effect, then if we multiply the same cause a thousand times, we shall produce only the same effect. Hence the mechanism being once acquired by the given figure and disposition of the parts, if we repeat the operations, we acquire by the same figure and disposition of parts only the same mechanism.

4. *Iron is rendered by friction the most highly magnetical, if it be of a determinate magnitude, mass, thickness, and surface. The magnitude, mass, thickness, and surface, may be determined by experience; but taking into account the nature of the iron and of the magnet.* The force communicated by the magnet to the iron, cannot penetrate down to every depth and distance in the iron. All active force in that which is contiguous, as it has a beginning, so it has an end. Motion slackens in proportion to the distance, and has its termination in some position of parts in the contiguous ens. In the elements themselves motion diffuses itself to a distance, according to the force, contiguity, elasticity, and figure of the parts. In a contiguous ens there is always resistance; hence it is that all motion tends to a state of rest, or to a natural equilibrium. An active, unless it be active from an internal or primitive force, cannot be continually active; for it possesses its own limits, like all other natural things. Thus the force communicated by the magnet to the iron, consisting as it does in motion, cannot penetrate

through all iron, at all distances. It is at the point of contact, or where the motion arises, that the force of the motion is greatest; because there it is that the spires and qualities of the motion are the most intimately conjoined. At a distance thence the motion terminates, as it were, in a state of rest, and degenerates into obtuser, slower, and less colligative spires, thus into a settled position of the parts. Within the iron, moreover, the force becomes gradually rarer, and dulls itself toward the interiors; just as is the case with the sphere exterior to the magnet. For there is a certain degree of force requisite to convert into a state of obedience to itself the partly free and partly colligated entities in the iron; a force which, by reason of the continual renitency of the parts, becomes gradually diminished. The communicative force, therefore, of the magnet with the iron, cannot extend except to a given distance, or to a given determinate depth in the iron. If however the iron be of considerable mass, thickness, and magnitude, it cannot by contact receive the magnetic power into itself to any great depth. If a regular figure has to be formed, it must be formed in its entireness; for unless it extend to the bottom or to the other side of the iron, it has at that part no radix, no terminus, no end, or inversely no beginning from which to begin; and inasmuch as beyond the terminus the effluvia lie in an irregular direction, nor have any regular relation to the surface of the iron, it follows that for want of a proper boundary the regular figure declines into a confused irregularity and is hence destroyed. For geometrical figures protect themselves in virtue of their own regularity; their abscesses and ordinates, horizontally and perpendicularly drawn, being enabled by the determinateness of their ratios to fortify and defend themselves against any impinging force; such figures for instance as circles, ellipses, parabolas, hyperbolas, and so forth. But if the figures be not perfectly geometrical, then are they not secure from injury; neither are they safe from the insultations of pressing bodies. Unless all the parts aim and conspire to the same figure, and be in contiguity one with the other, there is no acquisition of strength by which to maintain subsistence; particularly when the parts are themselves in perpetual motion. But if the situation of the parts be perfectly regular and geometrical, then one part cannot tend in any di-

rection opposite to the other; for one keeps the other attached to itself, and always in the same series and same line of connexion. Hence it arises that one cannot easily break off its connexion without the other. Hence also the whole nexus, compounded as it is of subordinate connectives, cannot be disrupted; unless a disruption has first been effected by some other cause acting elsewhere. How hard is it to effect a breach in a circle if it be perfect! but if it be anywhere already broken, how little force is requisite to go on breaking the arc, and causing the sides to collapse! Whatever is well connected together, may, on this account, be enabled to sustain a weight; but destroy the connexion (as in a rope), or let there be an hiatus between the parts, and the whole is without strength. In like manner, unless the communicative force of the magnet with the iron penetrate to the entire depth, it is void of all durability and strength. A figure is formed without radix, base, or limit; consequently incapable of maintaining itself by any connexion of parts; whence it subsists only for a time. In order therefore for the iron to be in the best manner invested with the conjunctive virtue of the magnet, it must be of a determinate mass and thickness; therefore, if we rub with the magnet the thicker part of the iron, it will not admit the conjunctive force so deeply as if in like manner we rubbed the thinner part. Hence we conclude that the figure also must be determinate, in order for the magnetic virtue to be received fully within the iron. For inasmuch as the force depends upon the regularity of the situation of the parts, unless the surface be regular and of a just form and dimension, magnetism can by no means be acquired. But as one magnet is better than another, and more deeply penetrates into the iron; so also is one piece of iron harder or softer than another; one is pure, another filled with heterogeneous matters; one is new, another is old; one is polished and smooth, another corroded with rust and roughened; one is crude, another is purified from its crudities, like steel; all of them therefore have different aptitudes of being operated upon by the magnet. Consequently all these things ought to be taken into account.

A POSTERIORI OR FROM EXPERIMENTS.

EXPERIMENT XXXI.

It is generally supposed that any iron, drawn over the pole of a magnet, becomes impregnated with attractive force. This opinion, however, is rendered doubtful by an observation of an opposite nature made by the celebrated De la Hire in *L'Hist. de l'Acad. Roy.*, A.D. 1692. He relates, for instance, that he took an iron rod, 6 inches long and 4 lines thick, to which he frequently applied an excellent magnet, which nevertheless did not communicate to it any attractive power, although to smaller rods it communicated a very considerable power; it was evident, therefore, that the iron must be of a determinate thickness in order to be capable of receiving force from the magnet; iron that is very thick being by no means so good for the purpose. This experiment appeared to me to be worthy of a further examination; in order to ascertain from it in what manner the magnet communicates its forces to the iron. Accordingly I took an iron parallelopipedon, 6 inches long, 1 inch wide, and 1 inch deep. This I drew lengthwise a few times over the pole of a magnet, the weight of which was $1\frac{1}{4}$ pounds, and its power such as to lift from its armature a weight of 7 pounds. To the plane extremity of this, as also to its margins and angles, adhered by attraction Indian dust and iron ore. By its angle or margin a very fine needle, scarcely $\frac{1}{4}$ of a grain in weight, was slightly attracted; but it was unable to lift the entire weight. It was evident, therefore, that the iron had become impregnated with a force, although but a small one. We then examined whether, at the same distance, the same mass of iron acquired from the magnet, in the course of a longer time, any greater strength. We let it therefore remain attached to the stone for the course of a day; and then, after being again plunged into Indian dust and applied to a small needle of steel, it exhibited the same but no increase of forces; these forces remaining unaltered even after repeated frictions upon the pole of the magnet.

2. We next procured three cylinders of iron equal in length, each being 4 inches and 1 line in length; these were terminated at one end by a circular plane, the other extremity being conical; the heights of the several cones were each $\frac{1}{4}$ of an inch. The diameter of the thickest cylinder was $\frac{1}{4}$ of an inch. This cylinder was drawn several times longitudinally over the pole of the magnet; it was then suspended per-

pendicularly to the horizon with its circular base downwards. A new steel needle was then applied, extremely heavy, but capable of being lifted, as was ascertained by several experiments: yet from the circular superficies a needle which was extremely fine was scarcely supported, even though it was not one grain in weight. A steel needle was also applied to the conical apex of the cylinder inverted, and though it was comparatively very heavy, being $1\frac{8}{10}$ of a grain in weight, yet it could be carried.

The diameter of the second cylinder was $\frac{9}{25}$ part of an inch. This also was drawn longitudinally over the pole of the same magnet; but to its circular extremity a needle of only one grain in weight could be appended, though it hung attracted from every point of the circular surface. When however the cylinder was inverted, it was found that from the apex of the cone facing downwards several needles might be suspended, the united weight of which was $7\frac{1}{2}$ grains.

The diameter of the third cylinder was $\frac{1}{10}$ of an inch; from the circular extremity of which a steel needle of only one grain in weight could be suspended; while from the conical apex might be suspended several needles, the collective weight of which thus adhering was 8 grains.

From these four experiments it follows, that the thicker the iron, the less by the same magnet is it impregnated with magnetic force; for it was the thinnest cylinder that received the most virtue, because it supported the greatest weight. Are we then to conclude that the thinner the iron is, supposing the length to be the same, the greater is the magnetic force with which it will be impregnated? The answer to this question we have endeavoured to ascertain; the result shewing that to attract a maximum of weight there must be a determinate thickness of iron, all other degrees of thickness possessing less degrees of virtue.

For the smaller cylinder, whose diameter was $\frac{3}{25}$ of an inch, and of the same length with the former, supported from its conical apex a weight of iron of 4 grains; while smaller pieces of iron wire, drawn over the pole of the same magnet, attracted only still smaller weights of iron; consequently there is a given thickness of iron which is invested with a maximum of attractive force by the pole of a given magnet, while all other pieces of iron, whether thicker or thinner, receive from the magnet a less degree.

The conical extremities however of the cylinders appear, at their obtuse apex, to collect or to condense the magnetic force; because from these apices was carried a much heavier weight of iron than from the circular and plane extremity. The cylinders I have described, were

made with a view to enable me to discover whether, between the thicknesses, lengths, and forces communicated to them by the magnet, there was any kind of proportion. From these experiments however I derived no satisfaction; as I was ignorant whether, by a greater dexterity on my part and by adopting other means, a greater weight of iron might not have been supported by the apices of the cones; not to mention, that variety in the figure of the apices gives rise to a considerable difference between the attractive forces; a circumstance occasioned by some other subtile and latent cause which will be elucidated by experiments in the sequel.

Let us next inquire into the degree of variation in the communication of the magnetic forces, when the iron is of a yet different figure. In the following experiments we made use of parallelopipeda, the lengths of which respectively were 4 inches.

3. The width of the first parallelopipedon was $\frac{1}{25}$ of an inch, its depth $\frac{2}{25}$ of an inch. This was drawn slowly and frequently, as also longitudinally, over the same pole of the magnet, so as to touch it with its broad side. In this case the attractive force was observed to be so great, that from its plane extremity could be suspended a weight of 25 grains. The same parallelopipedon was then applied to the same pole of the magnet, and was rubbed over it frequently in the same direction but so as to touch the magnet with its high or deep side; after which from the same extremity was suspended an iron weight of 35 grains. So that the magnet communicated to the iron a different attractive force, according to the different side of the iron in contact with the magnet.

The width of the second parallelopipedon was the $\frac{30}{100}$ part of an inch; its depth, $\frac{13}{100}$ of an inch; and when this was drawn longitudinally across the same pole of the magnet so as to touch the stone with its broad side, it was capable of supporting from its plane superficial extremity a weight of 145 grains. Being next drawn in the same direction across the same pole of the magnet, so as to touch the stone with its deep side, it supported from the same extremity only 64 grains.

The width of the third parallelopipedon was $\frac{1}{4}$ inch, its depth $\frac{1}{10}$ of an inch; this touched the magnet with its wide side, being drawn across the same pole, when it supported from its extremity a weight of 267 grains. Afterwards, however, when drawn across the pole so as to touch it with its deep side, it attracted a weight of only 57 grains.

Cor. 1. From these experiments it is evident, that the oblong and plane iron was endowed by the same pole of the magnet, with greater forces than the cylindrical: also that the greater degree of force was communicated to the parallelopipeda, 1. because the first supported

from its extremity 25 grains, while the second cylinder supported only $7\frac{1}{2}$ grains: 2. because the extremity of the parallelopipedon was a plane superficies, not terminating in any point, otherwise it would have carried a greater weight, while the cylinder could carry from its apex only a weight of $1\frac{2}{10}$ grains; 3. because the weight of the parallelopipedon was greater than that of the cylinder, and its width greater than the diameter of the cylinder.

Cor. 2. What is the difference of forces communicated to the parallelopipedon, according as they touch the magnet either on their deep or on their broad side? We might possibly suspect that iron, drawn both with its deep and with its broad side over the magnet, would receive a larger proportion of forces than if it were rubbed upon the magnet only upon its broad side. This was apparently observable in the case of the first parallelopipedon; but in the second and third the contrary obtained; since in these the forces, which were previously large, became considerably diminished by a friction of the deep side following that of the broad one.

Cor. 3. If we compare the attractive force in the parallelopipedon, which was 6 inches long, 1 inch deep, and 1 inch wide, with those of the first parallelopipedon, which was 4 inches long, the one will be to the other as 1 to 50. But if we take into account the thickness of each, then will the attractive force of the first piece of iron be to that of the other as $11\frac{3}{4}$ to 1. Consequently, if a force were communicated proportional to the thickness, it would follow that the parallelopipedon which was 1 inch thick, would have to carry about 2 grains, whereas only $\frac{1}{4}$ of a grain was attracted. There is therefore in a given length of iron some given thickness, which is impregnated by the magnet with a maximum of forces; beyond which all thicker pieces of iron, as well as all thinner, receive only a less proportion of force; for the lamella which was 4 inches long, $\frac{1}{4}$ inch wide, $\frac{1}{100}$ inch deep, when rubbed against the same pole of the magnet, received an acquisition of forces capable of sustaining only 12 grains.

On a consideration of the foregoing experiments, I began to suspect that the magnet was agitated by tremulous vibrations; that it was in these that its force consisted; that these were communicated to the iron applied to it; and that greater forces were observable in one than in the other, because the vibrations would be more easily received and retained. Inasmuch however as flannel applied to vibrating and sounding strings, immediately reduces the tremors and lowers the sounds, it appeared to me that it might also diminish or destroy the vibrations of the magnet. Hence over the pole of the same magnet was spread a triple layer of flannel, and over this again was drawn the third paral-

lelopipedon whose previous forces had been expelled by the action of fire; yet notwithstanding this, it received an attractive force equal to 9 grains. Next only two layers of the flannel were spread over the pole, and the iron was then drawn over the flannel, and received a force capable of raising 17 grains. Next only a single layer was spread over the pole, and the iron, when drawn over it, acquired a force capable of carrying 47 grains. The magnetic force being next expelled from the iron by means of fire, the parallelopipedon was again drawn over the pole, at a distance of 3 lines from the magnet; and yet it did not receive a force capable of sustaining more than 4 grains.

All these experiments clearly proved, that the forces of the magnet do not consist in any tremor of the parts; since it communicated them to the iron when it did not touch it, or when the iron passed over flannel which would suffocate the tremors; and that a communication of the attractive force is made at a considerable distance from the magnet. These circumstances indicate, that the magnet remains medially in the atmosphere of its forces, which are diffused to a considerable distance.

4. Since the experiments made with the former cylinders or parallelopipeda, did not satisfy me, I provided myself with six rectangular laminæ; of an exactly equal thickness, which was as nearly as possible $\frac{1}{100}$ of an inch, and as nearly as possible also of an equal length, namely, 4 inches; their width was respectively 1, 2, 3, 4, 5, 6 lines. All these were passed three times over the same pole of the magnet, with the same degree of force, and with equal rapidity; so that all might be equably impressed with the magnetic force. The smallest was the first, which suspended from one of its extremities a weight of only $1\frac{1}{4}$ grain.

The second, which was two lines broad, carried $10\frac{5}{8}$ grains.

The third, which was three lines broad, carried $7\frac{5}{8}$ ditto.

The fourth, which was four lines broad, carried 2 ditto.

The fifth, which was five lines broad, carried $1\frac{1}{4}$ ditto.

The sixth, which was six lines broad, carried $1\frac{1}{10}$ ditto.

Now these experiments prove only what we have above intimated; namely, that to be impregnated with a maximum of attractive forces, iron must be of a determinate width; and that other pieces of iron more or less wide are endowed with a less degree of force; and that there is no observable constant proportion between the widths and the forces.

5. Finally we had yet to ascertain whether, *cæteris paribus*, one piece of iron that was longer than another, was imbued with greater forces. Consequently I took a plate of iron of the same thickness

with the 6 former, 5 lines wide, 13¼ inches long; and drew it across the same pole of the magnet three times, as in the former cases. This carried from its extremity an iron weight of 25 grains. The plate was then shortened so as to be only 10 inches long; and when again drawn three times over the same pole of the magnet, carried 33 grains; when shortened to 9 inches in length, it carried only 19 grains; when shortened to 8 inches, it carried 17 grains; and when shortened to 4 inches, it carried only 1½ grains.

From this experiment it is likewise evident, that if the iron be of a given width and thickness, the longer piece is impregnated with a greater degree of force than the shorter; that it is only when we arrive at a certain given length, that it becomes endowed with a maximum of forces; and that if the length of the iron be altered, so as to become either greater or less, the iron receives from the magnet a less degree of force. In the foregoing case, the greatest difference of forces was observable between the length of 10 and the length of 4 inches; for the latter sustained a weight of only a grain and a half, while the other sustained a weight of 33 grains. Nor does there appear to be any given proportion between the length of the iron and the quantity of the forces.

EXPERIMENT XXXII.

A steel plate well tempered, 4 inches long, ½ of an inch wide, $\frac{1}{10}$ inch deep, was drawn three times over the pole of a magnet, slowly, and with a given degree of pressure; after this it carried an iron weight of 72 grains. Another plate which was made of soft iron, exactly similar and equal to the former, was also drawn three times over the same pole of the magnet with the same degree of pressure: this from its extremity was enabled to carry a piece of iron of only 10 grains. The frictions with the same magnet, when repeated, did not communicate to the iron any increase of forces; so that the magnet communicates to the steel a much greater degree of force than to the iron; and indeed according to this experiment seven times as much. Whether the same proportion obtains in other bodies of equal dimensions, made respectively of steel and of iron, I do not pretend to say. Numerous authors have remarked, that the magnet communicates more virtue to steel than to iron; but not one of them has noticed the exact proportion. Doubtless considerable difference will be found to prevail, according as the steel is purer or impurer; according also to the character of the iron, which, if taken from the mines of Sweden, differs from that taken from the mines of Germany.

EXPERIMENT XXXIII.

The magnet attracts iron more strongly than it does steel; and soft steel more strongly than hard; and hard steel more strongly than the hardest.

I remember that Hartsoecker has made the same remark; observing, that if a magnet can lift an iron ruler of the weight of three ounces, it will be able to elevate a ruler made of the softest iron and weighing at least 4 ounces. Dechales indeed maintains the contrary; unless we suppose that he was giving his opinion on magnetic forces communicated to a larger quantity of steel, as was intimated in a preceding experiment.

EXPERIMENT XXXIV.

Some magnets there are which communicate to iron a greater degree of force than others; nor do those which the most strongly attract a large mass of iron, or which are themselves the largest, always communicate as much virtue to the iron as the smaller and weaker.

This has been for a long time observed by all the makers of the mariner's needle; who are therefore always on the look-out for what they technically call *liberal* magnets, although they do not attract any large mass of iron. I made an experiment with a most excellent magnet, whose virtue was manifested at a distance of 13 Rhenish feet; and which, had it been well armed, would probably have carried 50 lbs. or more in weight of iron. On the north pole of this magnet were rubbed iron plates, the magnetic power of which was afterwards ascertained by appending to their extremities small weights. These plates being subsequently ignited in order to deprive them of their acquired magnetic force, it was found that a much greater attractive force was communicated to them by a small and weak magnet which was capable of lifting only 4 lbs. In managing this experiment, I took care that the iron should be drawn over the cognominal poles of each magnet, with an equal celerity, pressure, and number of times; but I could not come to any exact conclusion. Whiston confirms this remark by his own experience, as well as by that of the excellent Fatius and Colonel Wyndham. He however gave his attention to the celerity of the vibrations with which the same needle oscillated, when rubbed against different magnets; whence he remarked, that the directive force was not imparted to a needle by a large magnet better than by a small one.

We are however to observe that, for the most part, the stronger magnets communicate to iron a greater degree of force than the weaker.

From this experiment it seems to follow, that in all magnets the forces do not exist [*comparatas*] after the same manner; that one kind may be received by iron more easily than others. For it is extremely probable, that the strongest magnet emits from itself more forces than a weak one; otherwise how could it be the strongest? or how could it carry the greatest quantity of iron, unless it diffused from itself the greatest multitude of forces? These forces however are not received by the iron always in as great a quantity as those which flow from a weak magnet, and which are less in quantity. Consequently the forces of some magnets more accord with the fabric of the parts of the iron, than the forces of others.

In like manner there is also iron of a certain quality which receives little virtue from the magnet; while, in the meantime, there is other iron endowed by the same magnet with a greater degree of force.

EXPERIMENT XXXV.

If a piece of iron be drawn once very suddenly over a magnet, it acquires a certain degree of virtue; if we repeat the friction upon the same part of the magnet, and in the same direction, by raising the iron from the magnet, then, when it is drawn to its full length, the force becomes increased in the iron; until after repeated frictions, it has received all the force of which it is capable. For after this period, frictions upon the same magnet frequently reiterated, impart to the iron no further degree of force.

This is confirmed by Sturm in his *Physic. Elect.*, vol. ii., p. 1090. In this experiment the iron acquires only certain given forces from the magnet, and no more, although rubbed against the stone a thousand times; a circumstance which does not result from any incapability of receiving greater forces; but from this that the magnet cannot impart to the given mass any greater or more; for were the iron drawn over a more liberal magnet, it would acquire a greater force of attracting.

If the iron has not been drawn over the magnet, but only applied to it, then it does not become impregnated with the magnetic force, till after the lapse of some hours, as the celebrated Wolffe has justly observed; nor by this method is it made to receive so great a force as if it were drawn over the magnet. Since therefore the mere application of the iron to the magnet, or a rapid traction of it over the

magnet, does not communicate to the iron so much force, it is better to rub the pole of the magnet slowly with the iron and with a strong pressure.

EXPERIMENT XXXVI.

If the iron be rubbed against a strong and liberal magnet, it will receive from it a considerable power of elevating other iron; if it be again drawn over the pole of a magnet possessing weaker forces, it will lose a considerable portion of its former force, and lift a much less quantity of iron; possessing only the degree of virtue which the weaker magnet had communicated to it.

EXPERIMENT XXXVII.

If a plate of iron, drawn leftwards over either pole of a magnet, be imbued with attractive force and afterwards be drawn to the right, it will lose the greatest portion of the virtue which it had acquired from its former traction; while that which remains, will lodge in that extremity of the plate which last touched the magnet.

The iron therefore must never be rubbed against the magnet so as to be drawn both to the right and left; since after repeated frictions in this manner the iron will not be found to have acquired any virtue. This was formerly observed by Barlow and Riccioli in *Geograph.* 338. Moreover it has been observed by the learned Durham, that iron, thus rubbed, has its poles not in the extremities, but in or near the centre. Sometimes one pole is near the centre and the other at one of the extremities. Sometimes both extremities are attracted by the same pole of the magnet, and are repelled by the other pole. In this case the repelling pole always found the part attracting, near the centre. In other pieces of iron he observed that the directive force acted conversely, and that their extremities were plainly attracted and repelled in a manner contrary to the natural one. *Phil. Trans.*, no. 303.

EXPERIMENT XXXVIII.

When the forces exercised by a magnet upon iron removed to a given distance, are accurately ascertained according to our system of weights, then if several iron bodies be rubbed against a stone and impregnated with the magnetic force, and if the force of the magnet

upon the iron be immediately examined with a view to ascertain whether it has remained the same or decreased, it will be found that it has constantly continued the same without any decrement.

Several persons have recorded this observation; such as Norman; Newton on *Attraction*, chap. i.; Gilbert; and Hartsoeker, who on one occasion expressed to me his regret, that having been led into error by the assertions of Joblotus, he had said the contrary in his writings; for magnets never lose any of their virtue, although on one and the same day several pieces of iron be applied to them.

This we perceive therefore to be a great paradox; for if the magnet communicates as much of its own virtue to the iron as the iron receives, then a plate of a determinate magnitude would frequently acquire ½ of the forces of the magnet, and hence 8 plates would receive a force equal to that possessed by the magnet; and 64 plates, 8 times the force of the magnet; in other words, the magnet would be deprived of 8 times its virtue. But the magnet always preserves the same degree of force, even though within the space of an hour not only 64 but double the number of pieces of iron be drawn over it; nay, as is observed by Norman, even though it were rubbed by 1000 plates or needles.

Is the magnet therefore continually acquiring from some other source a fresh accession of forces, equal to that which it communicates to the iron? For its communication of forces cannot be the consequence of effluvia emitted from itself, because such an equable and sudden generation of effluvia as is required cannot take place; since numerous pieces of iron may be applied to it within a very short space of time. Whence is it then that these attractive forces so copiously and equably accrue to the magnet that it loses nothing by friction? Is it not rather that the stone communicates nothing of its substance to the iron, but only excites a force which is always latent in metal; and from a state of rest, brings it into a state of action? For it sometimes happens that iron when drawn over the magnet will lift a greater weight than the magnet itself; as De La Hire has observed in *l'Hist. de l'Acad. Roy.*, 1717. Does this excess of forces in the iron above those of the magnet arise from the iron or from the magnet itself? If from the magnet, there will be less in the cause than in the effect; which is absurd. But if there be latent in the iron a greater force, which the magnet only brings out into act, we may in some measure understand how it is that the magnet excites a force in innumerable pieces of iron on the same day. Still this supposition is incapable of actual demonstration.

EXPERIMENT XXXIX.

The magnet attracts pure much stronger than rusty iron; because rust is a species of vitriol, or salt mixed with particles of iron. We have however, in our chemical analysis of the magnet, above shewn that salt coerces the magnetic forces, and reduces them to a tacit state; the force of the magnet therefore does not act with such great efficacy upon rusty iron as upon pure. Consequently I can by no means agree with Tacquet, in *Clave Hippoc. Medic.*, chap. ix., who thus explains the matter,—*that from rust is expired the acid of iron, and that on this account the mater (or the magnet) does not perceive the odour.*

EXPERIMENT XL.

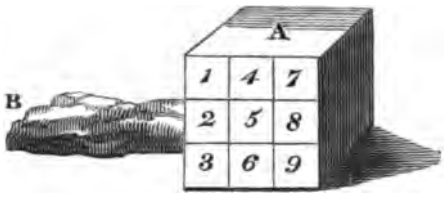
An unarmed magnet, capable of lifting an iron mass of two ounces, the greatest weight it can sustain, will not be able to lift another piece of iron of one ounce weight together with another piece of metal of one ounce weight; although its superficies be similar to that of the former mass, as Dechales has rightly observed.

EXPERIMENT XLI.

If a magnet be divided by a file into several parts, so as to avoid any concussion of the interior structure, then will the sum of the weights of the iron which all the fragments separately sustain, considerably surpass the weight which was before lifted by the integral magnet.

Seldom is a large magnet able to carry its own weight. I have known however many smaller ones possessing an attractive power capable of lifting ten or twenty times its own weight, and even more. I have seen the smallest magnets, whose power was fifteen times greater than their own weight. But inasmuch as a large magnet may be considered as a congeries of several small ones conjoined into a single mass, so these do not exercise so much force upon iron conjointly as they do separately. For it has been demonstrated in experiment 16, that the force exercised by the magnet upon the iron decreases in proportion to the increase of the distance. Thus Fig. 45, let A be a magnet capable of lifting the iron B. Let it be conceived to be divided into nine parts, as exhibited by the figure: it will be directly seen that the iron B is immediately applied to the parts 1, 2, 3; but that it is distant from the parts 4, 5, 6, by the thickness of the parts in the anterior series;

Fig. 45.



wherefore these act upon the iron only in like manner as the magnet would have acted, if removed to the like distance from it. But inasmuch as parts 7, 8, 9 are much more distant from the iron B than the middle series, these again will the less operate upon it. Still by their virtue they will assist the action of the first series upon the iron. But if the nine parts had been separated from each other, and the iron had been applied immediately to each, then being in contact with each part the iron would have been attracted with its greatest force; whence the sum of the weights attracted by these nine parts would considerably surpass the weight carried by the united mass A. The smaller the parts into which A is divided, and to each of which the iron is presented to be lifted, the greater will be the weight elevated by all together. But the greater the mass A, the more distant are the posterior parts from those to which the iron is applied, and therefore the less can they operate upon it.

EXPERIMENT XLII.

The larger are the magnets, though not of particularly great power, the greater is the distance to which they diffuse their forces. Consequently, excellent but small magnets do not so widely extend their power, as the large though more inert ones. This is confirmed by Hartsoeker, who says he learnt it from experience: hence three or four magnets, well joined together, act at a greater distance than each separately.

The attractive force is frequently diffused to a great distance from the stone. Some experiments I made with a very large magnet, which manifestly operated at a distance of 14 Rhenish feet. The two following are excellent methods of ascertaining to what distance from the magnet the force extends itself. 1. Place an extremely fine needle of steel upon the surface of water put into a vessel, so as to float in the middle; let a magnet be next located at a considerable distance, then be

* In the original, plate IX., fig. 3.

gradually brought nearer, so that the line passing through the poles may point toward the needle. Let the magnet continue to approach, till the needle begins to be moved; it will then float toward that wall of the vessel which is next to the magnet. 2. Let an extremely mobile needle, 6 inches or more in length, be placed in its meridian; marking the degree to which its extremity points; then let the magnet, placed at a considerable distance, be gradually brought nearer, so that the axis may be perpendicular to the needle and in the same horizontal plane, until the needle begins to be deflected from its position; the distance between the two will be the length to which the magnetic forces are extended, or the length of the active ray. This method has been mentioned also by Fontenelle, in *l'Hist. de l'Acad. Roy.*, A.D. 1717.

EXPERIMENT XLIII.

The various fragments of magnets may be conjoined into one mass, which will exercise considerable power; provided that lead be poured in between and roundabout the parts. These fragments require to be arranged in such an order, that the poles of the same name look in the same direction; for in this case, they are disposed in the same manner as the parts of the large magnet would have been by nature. Thus art, imitating nature, composes the larger mass out of the smaller. This was known to Deschales and to many others, who verified the same by experiment.

EXPERIMENT XLIV.

It sometimes happens, that a large magnetic mass does not exhibit much attractive force; when, on the other hand, the same, if dissected into many fragments, exhibits a small portion of itself endowed with considerable forces, upon which, as upon a heart situated in the middle of the stone, depends the whole force of the magnet; which, being previously dispersed throughout the larger mass, had either been prevented from issuing out, or else, from being distributed in every direction through the mass, had debilitated the polar localities.

END OF VOL. I.

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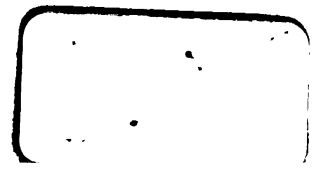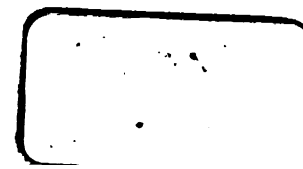
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